Socio-Organizational Factors for Safe Nuclear Operation

Volume I

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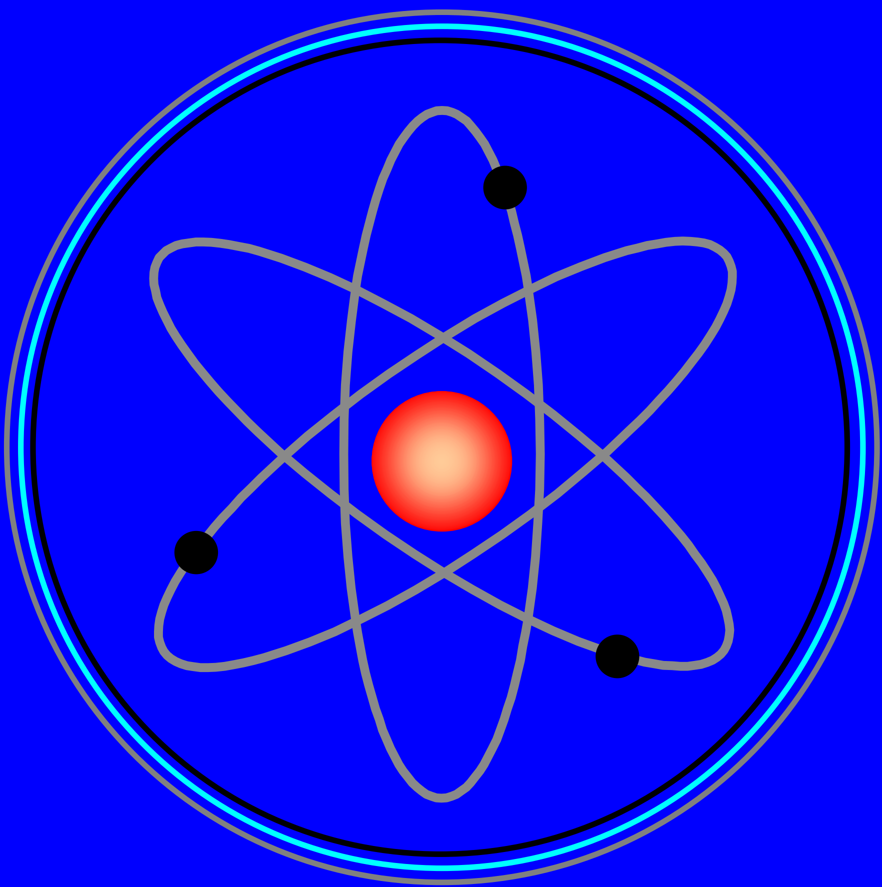

Philippe Fauquet-Alekhine (ed.)

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Socio-Organizational Factors
for
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Front cover:

The front cover has been designed by Ph. de Cuntreval.
It represents the nuclear power centered in the yellow-red disk, image of the energy enforced by surrounding particles, and kept safe by three concentric circles. These circles represent the three barriers between the radioactive material and the environment surrounding the plant: the fuel sealed metal tubes cladding, the heavy steel reactor vessel and the primary cooling loop, and the containment building.

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Co-author of the audiovisual course DEDALE-IFSA "Briefings", he also established the Data Bank of questions and exercised during 6 years, on behalf of the Board of Examinations of the DGAC (Direction Générale de l'Aviation Civile, French regulator for civil aviation), the position of Manager of Matter for Human Factors exams for aircraft and helicopter pilots' qualifications.
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Introduction

The purpose of this book is to gather chosen papers concerning presentations made during congresses or lectures in conferences in which LARSEN participated.

The papers are structured in three chapters on the following topics:

- **Human Factors policy and organization for French nuclear reactor fleet**
- **Human Performance and the description of means implemented for its enforcement**
- **Simulation training from the description of training sessions to the analysis of specifics topics**

Concerning the congresses, only short abstracts were given in proceedings. In these cases, the papers refer to the corresponding proceedings. Concerning lectures, no proceedings were planned. Nevertheless, papers have been written for each of them and have been chosen here because of their interest relating to nuclear operation. In these cases, the papers refer to the corresponding lectures.
We thus obtain a set of interesting papers related on French Nuclear Power Plants (NPP).

The quality of the contributions in this first volume "*Socio-Organizational Factors for Safe Nuclear Operation*" is guaranteed by a scientific committee composed of professors, doctors, industrial executive managers who have carefully reviewed the papers according to their own fields of skills.

These papers are written to be used: feel free to pass on widely the contents of this book.

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Executive summary

Chapter I

Human Factors policy and organization

Humans Factors in French Nuclear Industry

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http//hayka-kultura.com/larsen.html

Abstract

The Human Factor Policy for French nuclear reactor fleet is presented. The key job of Human Factor Consultant (HFC) is described from its genesis in the company to its today re-questioning. The different skills domains of the HFC are commented.

1. Introduction

Electricité de France Nuclear power plants are submitted to strict formal rules. Respect of these rules, and especially functional parameters or materials configurations, allows to guarantee in case of technical problem, that the process and organization will manage to control the situation and the installations. The aim is to protect Human and his environment from radioactive contamination by the containment of nuclear coil and derivative products.

A deviation with regards of referential (a valve in a state not in accordance with requirements for example) can be treated as a significant safety event. Such a deviation must then be analyzed and explained to Nuclear Safety Authority (the national regulator). It is clear that for EDF industrial company, such deviations are not acceptable as they involve and discredit dispositions adopted to guarantee nuclear safety on power plants.

Consequently, all means are implemented to avoid occurrence of exploitation events concerning nuclear safety (see Fauquet 2002, 2003, 2004). By exploitation event, it is necessary to understand a gap between realized work and expected task. Any gap detected leads to a treatment (Fauquet, 2007, 2008) and is assessed according to the INES scale. Quasi entirety is classified at level 0 ("no importance from the point of view of safety ").

The contribution of the Human Factors Consultant (HFC) and the policy of Human Factors in the company, help to avoid occurrence of exploitation events.

This paper will give a short description of the HF policy and will explain what has been identified as a key competence which is the one of Human Factors Consultant, and why.

Then it will expose briefly the four domains concerning the missions of a HFC on a nuclear plant organization.

2.Human Factors policy and Human Factors Consultant

Let us first suggest a definition for "Human Factors" in industries.

The Human Factors (HF) are the factors which contribute to the occurrence of a situation by the action or the decision of Human, individually or collectively: behavior, attitudes, organizations, decisions, and all their interactions.

Thus, it is fundamental to notice that HF are centered on the work activity. For industries such nuclear exploitation, one of the important implication parameters is the formal prescription (Fauquet et al., 2002). Other high risk industries or companies are concerned at the same level; chemical industries, refineries, aircraft and navy companies (Amalberti, 1996 et 2001; Clostermann, 2010), for example. Process is so complex, and stakes are so important, that companies and industrial firms are involved in heavy training programs with the use of expensive full scope simulators (Fauquet-Alekhine, 2009). And since 2006, EDF is involved in a specific Human Performance Program which one the Human Factors experts must sustain (Fauquet-Alekhine, 2010; Colas, 2001; Rousseau, 2008).

Taking into account the HF aspects is thus quite important. This has been notably pointed out after the nuclear Tchernobyl accident (Ukraine) during which the Human contribution to the accident occurrence has been significant. It gave rise to the realization that the process safety could not be only or at least mainly based on technical automatic controls. The place of Human inside the process had to be reconsidered.

For the French nuclear industry EDF, one of the main points has been to development a HF policy, with the creation of the job on each nuclear power plant: Human Factors Consultant. The HFC must help to take into account the HF dimension at work. According to my colleague of Air France, Jean-Philippe Barat, "taking into account the Human Factors dimension at work is to make visible what is invisible".

Personally, the definition can be: Human Factors are factors which contribute to the case of a situation due to action or to decision of Human, individually or collectively: behaviors, attitudes, organizations, decisions, as well as all interactions between them.

The HFC is involved in 4 domains:

* This work has been presented at the *J. Int. de l'Enseignement et de le Recherche Maritime*, 25-26 mars 2010, Marseille, France. It has been printed in its French version in *La Revue Maritime* under the title "Les Facteurs Humains dans l'industrie nucléaire française", déc. 2010, n° 490, 4-11

- Contribution to feedback event and work activities analysis: analysis of the organization (remedial, or proactive such as socio-organizational and human impact analysis), event analysis.
- Support and advice to departments or teams: projects of teams, analysis of particular situations such as controversial, re-organization, ...
- Support and advice to the unit head management.
- Development of HF knowledge: lectures and demonstrations in departments or teams, in trade academies, in classroom training sessions and training on simulators, in the deployment of the Human Performance Program with notably Manager in the field and Reliability Practices (Human Performance tools).

At the beginning of the 90's, when the HFC job has been created, it was rigged by technicians, people from the industrial process trades. Soon it as been pointed out the need of Human Sciences academic knowledge for such a job, and around 2000, people from Human Sciences universities have been employed for the job. It appeared to be a good choice from the analysis standpoint, but nevertheless, it was difficult for a lot of those persons to be effectively efficient concerning the understanding of the industrial process. It has been then written, in 2002, a frame of reference for the job, after a national study of one year, in which have been recorded all the competences required and all the topics on which the HFC could work. The following years, some few people with both the technical and Human Sciences competences where chosen for the job, and in parallel, the national division, with the support of the Research and Development division, have created a specific Human Sciences Master for the technicians craving for the HFC job. In 2008, the first "students" attended the Master session.
Today, the national division is thinking about the needs for the following years. With the strains of the economic market, with the new projects in which the HFC have been involved like the Human Performance Program, the job has changed, and expectations have to be reconsidered. Again, the national division is leading an analysis, the results of which are expected before 2012.

Nowadays, the typical organization on a nuclear power plant, for the HF management is as follows.
The HFC is usually attached to the vice-director Safety-Quality, who is attached to the head director of the nuclear power plant. This close relationship to the head management of the plant has shown a lot of advantages for the HF dimension to be sustained by the whole management.
The operational departments of the plant have designed one HF correspondent. The aim is to create a short link between the department and the HFC, in order to make the people of the trade feel more easy to speak of HF questions. Those correspondents meet four times a year to share about problems, solutions, or knowledge.

The HFC also works with the social partners, which are the social worker, the work medicine, the union trades, and of course, the management and the teams.

We shall describe here after briefly every domain in which the HFC is involved. The readers will note that the HFC is definitely oriented in a safety management way.

3.Feedback event and work activities analysis

One of the main contributions of the HFC for this domain is the safety event analysis.
Safety event analysis is curative (comes after safety events). It is an important part of the HFC's activity for at least two reasons:
his competence is needed to help to find the deep causes of the event,
by doing this kind of analysis, the HFC reaches some information that helps him to have a better comprehension of what is going right or wrong on the plant, and this information can help him for other analysis.

The treatment of the safety events falls under logic of a framework which is declined, in the ideal, in several phases:
a-the collection of the facts near the actors by the writer of the final report, in order to trace the chronology of the event as soon as possible, and to work out a first analysis,
b-the meeting of the actors of the event in collective discussion with the HFC, to work out the tree of the causes, to identify the failing states and inappropriate actions, and to put under discussion the elements of comprehension,
c-the outline, at the time of this meeting, of the corrective actions,
d-the drafting of the report and its validation by the actors,
e-the validation of the report by a collective authority specific to the trade (see its functional description and analysis in Fauquet, 2004),
f-the validation of the report by Management of the power plant,
g-the diffusion of the teaching of the analysis report in the teams.

Items b and c are fundamental because they contribute to put under discussion, within the group of workers, the practices of work which possibly led to the event. This setting under discussion, which is articulated in particular around the elements of comprehension of inappropriate actions, makes it possible the group of workers to make evolve its individual and collective practices, to decide together this evolution, in order to apprehend a similar situation in a different way, and to reduce the probability of renewal of the event. Thus, the context of the event is thought and discussed as if it were necessary to replay it differently in order to apprehend next similar situation differently.
In the same way, items e and g make it possible to share on these changes of practices with the peers, and other actors potentially concerned with these changes.

The fundamental difference between, on the one hand items b and c, and, on the other hand, items e and g, lays in the objective of transformation and sharing between workers associated with these transformations.
Details are fully developed in Fauquet (2005), and the individual or collective analysis presented are based on the works of Clot (1999) and Clot et al. (2002), Vygostki (1930) and Scheller (2001).
The results and conclusions of such analysis are then used to adapted organizations, at the nuclear power plant level, but also at the national level.
Annual safety analysis gathers those information for each plant, and global analysis is done for the whole division. Among the tools used, the data base called L@cid gives accurate details of each event which allow fine categorizations of the events and statistical approach of the data. HFC are involved in entering data and analyzing them.

4.Support and advice to departments or teams

This kind of support can be involved by national organization or by local requests.
One example of national implication is the SOH impact analysis.
SOH impact analysis is at first proactive (the analysis comes systematically before the action), and must integrate event and work feedbacks and thus, can also carry on a curative aspect of work analysis.
SOH impact analysis is connected to a national modification of the materials. This modification is first studied from the technical standpoint, and then a large analysis is done, led by the national departments with the help of a few power plants called "head of series". This analysis needs usually several months, and is enriched by the feedback given by the "head of series" plants. It concerns impacts on the equipment, the organization, the resource, the training needs.
Conclusions are then gathered and send to other plants with the modification documents in order to be taken into account. Sometimes, the plant management decides to engage a new SOH analysis to be sure that the analysis will take into account all the specificities of the plant (technical and organizational). This local analysis is led by an engineer TLI (Local Technical Integrator), supported by the HFC if needed.
Support and advice to departments or teams also concern local requests as actions concerning the management of people and of work activities. It can be changes of organization, of process, for example, but it can be resolution of controversial situations or conflicts inside or between the teams, or between management and teams.
Some specific meetings help the HFC to give advice to the departments: every month or every two months (depending on the department organization), a work safety group (description and analysis in Fauquet, 2004) takes place to discuss all safety points of interest.

5.Support and advice to the unit head management

The HFC is expected to give support and advice to the unit head management at least in two ways: on request and according to his own analysis.
On request, the unit head management asks the HFC specific analysis concerning organization changes, management decisions, both before or after their application. It can be formal (with a study or analysis report delivered by the HFC to the management) or informal (a discussion in the director's office).
According to his analysis, the HFC can ask the management to pay specific attention to the consequences of a decision of a new organization. To be able to do it, the HFC must make permanent macro analysis of the plant works, by gathering all the knowledge he has concerning every thing on the plant. To be efficient on this kind of job, it is important for the HFC to be involved in a lot and diverse analysis on the plant, and to be in touch with most of the operational departments.
Some specific meetings help the HFC to give advice to the management staff of the plant: every month, a safety technical group takes place to discuss all safety points of interest.

6.Development of HF knowledge

During the past years in most of the cases concerning this domain of his work, the HFC was involved in some lectures and demonstrations in departments or teams. On request of the teams, or to improve some work practices (Fauquet-Alekhine, 2009, 2010), the HFC could work with the pilots on full scope simulator during training sessions.
Since 2007, with the Human Performance Program, the HFC is much more involved in the training sessions, both on maintenance and piloting full scope simulators, and both in conception and teaching of the training programs. HFC also helps for the management to enforce their action in the field, according to the needs of the teams.
Besides, trade academies have been created for people recently employed in the company. In this frame, the HFC in asked to provide specific lectures concerning HF policy on the plant, and concerning the reliability of work.
And for managers who are concerned by operational work, the HFC is asked to make lectures concerning the event analysis methods.

7.Concluding remarks

History of the French industrial process at EDF have shown how much important is to take into account the Human's place in the process, whatever is the industry (see for example Colas, 2001; Clostermann, 2010). The EDF company has built since several years a Human Factors policy which must answer these kinds of needs.
To help the success of such a policy, an expert is involved in the safety management: the Human Factors Consultant. On every nuclear power plant, one to three persons are employed for such a job.
Organizational feedback and studies have pointed out that, for such a job, both technical and Human Sciences knowledge and competence were required. In this aim, the company, with the help of other big industries and universities, has created a specific Master.

In parallel, the company has understood that the Human Factors policy had to be adapted periodically. This has been done at the beginning, in the 90's, done again in the 2002's, and again it is in progress now with expected results before 2012.
As we can see, Human Factors policy needs specifics means and organization, and constant adaptation to be efficient.

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Industrial safety and experience feedback: the case of French nuclear power plants

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http//hayka-kultura.com/larsen.html

Abstract

The French nuclear power plants operated by Electricité de France are of type "pressurized water reactor. This collective design promotes a capitalization and a pooling of means, including experience feedback (REX), which must be a force for operation of this nuclear fleet.

The REX and integration are satisfactory when they register in two dimensions at least, one is organizational and the other one is time. But the organizational dimension can be easily reduced, and the dimension of time is often "dilated".

The ideal form of the organizational dimension can be reproduced in a closed loop that uses the findings, results, analysis, and solutions that should be implemented. These solutions, implementing the integration of findings from learning, give rise to new findings and assessment of effectiveness. The loop is closed.

The ideal form of the dimension of time, may be summed up in "as soon as possible".

Thus, the closed loop of the organizational dimension joins the effective nature of the REX, and the ideal of the time dimension joins the efficient nature of the REX.

Frequently encountered problems reside in the non-closure of the loop and the inability to quickly, or even to do everything simply. Yet, each actor of the company is aware of this need. Despite this, the experience feedback of the REX, show all the difficulties to calibrate the REX process at the right level.

To work this broad question and solutions, the management of the Generation division of EDF (DPN) launched a project in 2007, the REX project.

The paper outlines the various stages of diagnosis, solutions research and deployment thereof, and the success factors identified both locally and nationally.

The solution adopted to achieve the target model is an organization of the REX and its integration by the CAP: the Corrective Action Program. To ensure the adequacy to the needs of nuclear plants and verify the feasibility in the context, the stage of diagnosis was followed in 2010 by a phase of experimentation on a few plants, before engaging a global deployment anticipated in the second half of 2011.

1.Introduction

The French nuclear power plants operated by Electricité de France are divided into 19 plants scattered throughout the French territory. All these plants are of type "pressurized water reactor" (PWR). This collective design promotes a capitalization of learning from experience and sharing means that are a force for a safe operation of the nuclear power plants. Thus, if each plant (2-6 nuclear reactors each) has a degree of autonomy, there exists nevertheless a national organization in many areas that promote exchanges, centralization of information, analysis, and redeployment of innovative solutions.

The experience feedback must, of course, proceeds of such an organization, both at the local level as at national level. Feedback is a broad topic that inevitably includes many themes in an industry as complex as the production of electricity of nuclear origin. And as any action or any project, it must contribute to strengthening nuclear safety (see Fauquet 2002, 2003, 2004), for obvious reasons of every day protection of humans and environment, and because a risky system operation implies the continuous demonstration of a high level of safety (Amalberti, 1996 and 2001). This allows to guarantee in case of technical problem, that the technical process and the organization will succeed to control facilities in the situation.

It should be noted that the objective of nuclear safety is to protect human and his environment of radioactive contamination by the containment of the core and derivative products.

The experience feedback concerns many areas at various levels; we cannot here expose all. Also we have chosen to focus the presentation on a large enterprise project, the "REX project" (in French: “le Projet REX”), explaining its genesis and its deployment, and illustrating it from concrete examples of the operation of Chinon nuclear

* This work has been presented at the *J. des Grandes Ecoles de la Mer « Facteur Humain & sécurité maritime »*, 26-27 January 2011, Le Havre, France.

power plant. Before it should be appropriate to specify what is expected in terms of experience.

2.An efficient effective feedback loop

The experience feedback, or REX for “retour d’expérience” in French, comes from experience, as its name indicates. This experience, manifest in the form of results, findings (qualitative or quantitative), gives rise to a formal or informal analysis first. Within such a coordination, the experience is able to be integrated in a process of learning from experience.

As specified above, the REX concerns many issues in various areas. For example, the area of the worker in a given activity, the area of a professional practice and know-how, the area of a department organization, the area of an industrial site organization and interactions of departments, trades and external entities to the plant… This non-exhaustive list is very few of the multitude of possible examples.

The REX and its integration are satisfactory when they register in two dimensions at least, one is organizational and the other one is related to time. But we will see that the organizational dimension can be easily reduced, and that the time dimension is often "dilated".

The ideal form of the organizational dimension can be depicted so: it is a closed loop that uses findings concerning results. These findings give rise to an analysis that produces solutions that should be implemented. These solutions, implementing the integration of learning from findings, have an effect on the results giving rise to new findings and assessment of effectiveness. And the loop turns without stopping.

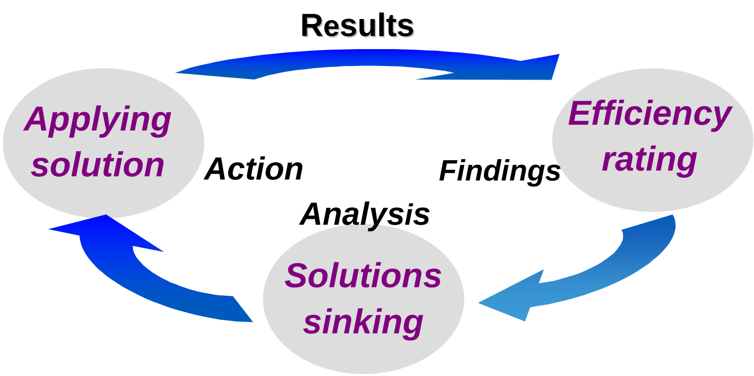

Fig 1. The REX ideal closed loop of the organizational dimension.

The common problem is the non-closure of the loop. It can intervene at various stages. For example:

- the findings exist but are not exploited: the loop stops before the question of the need to be analyzed,
- the analysis is made, solutions are proposed, but their implementation is not effective,
- solutions are implemented, but their effect is not analyzed because the findings are poorly targeted.

Concerning the ideal form of the time dimension, it is simple since it can be summarized as "as soon as possible".

Thus, the closed loop of the organizational dimension is related to the efficacious nature of the REX, and the ideal form of the time dimension is related to the efficient nature of the REX.

Each actor of the company is aware of this need. However, the experience and the feedback concerning the REX show all the difficulties of businesses to sink the REX process at the right level.

Let us consider two examples from the Chinon nuclear power plant to illustrate these remarks.

The first concerns the maintenance of nuclear reactors. Annually, each reactor stops for outage and to renew the coil. At each outage period, some people are surprised that "everything happens as if every time we rediscovered what is a outage, with the same problems". If these comments cannot be generalized to the organization of a outage, the fact remains that there are too many actors of the outage who has this feeling. In this type of situation, the REX is integrated, but only at the personal level: indeed, the person confronted with the same problem from one outage to the other has implemented solutions that s/he keeps in mind, to more quickly handle the same problem when renewing. But what expects the worker is that the REX will be integrated in the organization, so that if the problem arises the solution exists or if they have to deal with, it requires less energy than the first time. Here, in the area of the intervener, the REX is integrated, but at the level of the organization, this is not the case.

The second example concerns the REX of a profession in a department. The technicians complain about the absence of REX. However, a decision was made by the department management to formalize a REX meeting concerning the end of the outage. The finding is that this decision has remained at the state of intent.

Each actor is aware of the need for the integration of the REX and also people have a natural need of REX for any work activity. A simple experiment was made on a dozen of groups of 10 to 20 people each on the nuclear power plant of Chinon. It has been proposed to people in a room to engage themselves in a particular work activity. Although conducted in room and far from the usual technical activities, the general components of a classic work activity were encountered, namely achieving a work activity with:

- a constraint of time,
- a requirement for such a modus operandi.

- the need to summon a know-how developed for a long time,
- disturbances making the achievement of the outcome difficult,
- a request to achieve a specific result.

The work activity was to count the number of "F" in a 4 lines text that would be projected on the screen (see Fig. 2). In any case, the outcome seems fairly easy. However, the context was the following, complicating the realization of the application with reference to the above constraints:

- the text was shown during 20 seconds only,
- the text led to be read and letters had to be counted at the same time, and it was forbidden to read the letters one by one,
- the need to summon a know-how developed for a long time concerned the reading skills,
- the text was in English (while people were French), in tight uppercase letters.

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Fig. 2. English text submitted to French people during 20 seconds in order to count 'F' letters whilst reading the text at the same time.

For a group taking the test for the first time, the results may vary between 2 and 7 "F" detected per person, with a high proportion for the values 3 and 6. The typical distribution is shown on Fig. 3.

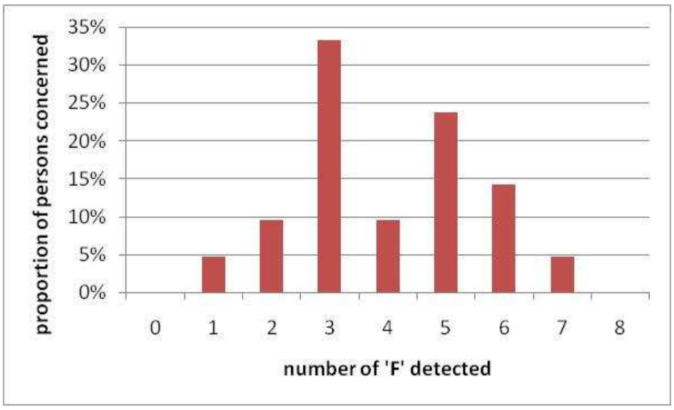

Fig. 3. Typical distribution of the number of French people watching the English text (see Fig. 2) submitted during 20 seconds and counting 'F' letters whilst reading the text at the same time: two extremes appear around 3 and 5.

Before taking this test, the instructions have been presented, the text was projected 20 seconds and hidden, and a discussion followed to compare the results of each person and discuss the difficulties encountered. After this discussion, the facilitator suggested to work another subject without moving back to the text and thus without knowing the exact result: "and now, I propose to following the presentation without I give you the correct result, the number of F in the text. We shall not come back on this test, you will never know the result, unless you manage to find one day the text elsewhere, but it is not me who will give you the solution. What do you think of it? Would you like to know the right result? "
For the last question, between 70 and 100% of these groups usually replied to be very disappointed not to know the right result. When it was asked the reasons for this disappointment, the participants explained their need to know how to position themselves to the expected result, to better understand where they had errors, and possibly how otherwise do a next time, even if it was just a test without consequence.

This experience shows the spontaneous expectation of each one in terms of REX. If participants expressed such a desire even for a harmless test, it is quite easy to imagine how much they are expecting a share after a professional activity. It is important to note in this experiment:

- the spontaneous character of expectation of the REX,
- the existence of this expectation even for a harmless activity.

The result of the demonstration suggests that almost everyone in professional life is spontaneously expecting REX and that almost each one is predisposed to participate.

In this condition then, why the REX and its integration do not work as everyone would expect it?

To work this broad question and solutions, the management of the Generation division of EDF (DPN) launched a project in 2007, the REX project. Indeed, training people (Fauquet-Alekhine & Pehuet, 2011; Pastré, 2005) increasing interventions (Fauquet-Alekhine, 2009 and 2010a; Colas, 2001; Rousseau, 2008), enforcing the safety through event analysis (Fauquet, 2007 and 2008) or through socio-organizational analysis (Clostermann, 2010; Fauquet-Alekhine, 2010b), are not sufficient if the socio-technical system weakens over time (De la Garza & Fadier, 2007; Heimann, 2005; Reason, 1993 and 2008).

3.From diagnosis to implementation

The REX project started by a step integrating diagnosis and studying practices and organizations at the international level.

The approach consisted in:

- Taking into account analysis by nuclear industries.
- Participating observations on French nuclear plants.
- A in-depth benchmarck in the United States.
- Listening to many actors at all levels of the organization of EDF (also from other divisions than the DPN).
- A thorough sharing of the diagnosis.

The major findings for the company organization were the following:

- The REX from the national level takes place over the local REX.
- A parallel REX exists to the operational activity, enhanced by the treatment of the safety events, and not enough through the success of the interventions.
- Developments of the REX is done by slides which have been by time superimposed while forgetting to rethink the whole from local need standpoint.

The solution adopted to achieve the REX target model is an organization of the REX and its integration by the PAC : « le Programme d'Action Corrective », inspired by the American CAP (Corrective Action Program). The PAC will be presented in the next section.

To ensure the adequacy of the solutions with the needs of nuclear sites and verify the feasibility in the context, the first step was followed in 2010 by an experimentation step on a few plants, before engaging a global deployment planed in the second half of 2011.

To enable the success of the project, efforts focused in particular on the following points:

- Identify quick wins in 2010 that restore confidence and socialize them.
- Involve all the plants in the project in 2010 via existing networks and with the help of a "mirror group".
- Adapt the deployment of the project to the situation of each site.
- Maintain operational system during the transitional period of deployment.

These actions have in support two transverse components essential for the achievement of the objectives:

- A component "Means, methods, skills, and tools" to build the necessary means for the implementation of a renovated REX organization. Output products expected: a corpus of knowledge, methods and tools so that each actor has prerequisites required in the field of the REX; training for key actors (managers, preparation operators, REX project managers…) and for newcomers.
- Another component "Change management, culture and behaviors" to create the necessary conditions for the development of the REX. Output products expected: awareness, in the short term, of the way to go, and a change in behavior, both at the national and local levels.

4.The necessary structuring of the experience feedback and of its integration

The solution adopted to achieve the target model is an organization of the REX and its integration by the PAC: the Corrective Action Program (in French: Programme d'Actions Correctives, PAC).

The PAC is based on a frequency of analysis of the input findings in a computer database, and a closure findings-analysis-actions-results-findings...

Identification of the REX and the material of which it is made up are done via the findings every day D_i. Any person on the plant is involved in this work of computer input.

The consolidation of data entering is made at D_{i+1}. It is to verify the characterization of the findings to ensure homogeneity of these characterizations. This point is fundamental because if there is heterogeneity at this level, trend analysis and statistical analysis are generally impossible.

At D_{i+1}, the findings are prioritized, assigned to actors identified as in ability to process the findings and solutions. This means that every day, all of the findings entered the day before are studied.

The actors of this work analysis at D_{i+1} are part of the department management and involve themselves in the analysis for their department.

The integration of the REX is done through the analysis of two types: specific analysis and trend analysis. These are made at D_{i+2}, posted weekly and kept in check weekly and monthly. The aim is to appreciate whether the findings are archived for memory without action, or for simple action, or for specific analysis. The whole gives rise to trend analysis.

These findings being made on a daily basis at all levels and in all occupations, and then followed by various time scales, the effects induced by actions will lead to findings which will close the loop.

In addition, a review of efficiency is scheduled each month. In parallel, the conclusions are settled up in periodic performance reviews.

This target structure is not yet reached in the organization of Chinon nuclear power plant. It was chosen to go through a transitional phase, with a gradual integration of the objectives. First, the quality of the finding entering process and data extraction tool has been optimized. In parallel, the presence of the managers in the field has been worked to achieve a level of completeness and relevance to the issue. Secondly, a weekly analysis of the findings has been implemented. The third time is to come to achieve the target model.

5.Conclusion

We find that taking account of feedback and its integration are not obvious work activities to be implemented effectively and efficiently in the industry. They are daily disturbed by the industrial constraints induced by the real time, easily suffer from a lack of coordination of the treatment of the REX, and upstream, can remain in the state of intent if the framework is not clear. Their upgrade involves a solid diagnosis, and a deployment of their solutions integrating both careful planning and appropriate means.

According to the proposed solution (the corrective action program or PAC), the induced effects can hit the practices and culture of company. In this case, a component of accompanying change is necessary. This implies registering the project in the long term: a brutal and decreed change could lead to failure.

The feedback of the experience feedback itself also warns the sustainability of the solution: if the current state of the experience feedback suffers from an accumulation of poorly coordinated actions and decisions which remain in the state of intent, how the new organizational system will prevent this with time? Another potential danger is displayed: the drift of the system. it will need to ensure that the CAP will not turn into a machine made to accumulate observations with actions not dealt with. The planned organization should avoid such excesses.

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Safety and Reliability for nuclear production

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Abstract
Nuclear production consists in producing electric energy from nuclear energy. If the basic idea is quite simple, the implementation gives complex socio-technical systems that imply strict rules and requirements to guaranty the safety of the industrial plants, and of course of the people working there or living around. This means that safety and reliability are definitely linked together, from the equipment standpoint as from the organiszational standpoint.

This paper explains how French nuclear industry operated by EFD, while not concerned by major accidents, is able to learn from the world-wide industrial feedback.

All what is presented here shows that “no accident on the nuclear fleet” does not mean “no re-questioning”. On the contrary, it shows how the EDF company holds the “permanent re-questioning” as the meaning of “no accident on the nuclear fleet”.

Why such a subject and why such a title?
The network Aquares49 wanted to gather around the table specialists of risky and complex socio-technical systems for them to present to physicians what had been set up in order to make work activities more reliable. In this aim, air line, merchant navy, nuclear industry and medicine specialists had to present their point of view concerning their own discipline. In this perspective, reliability was obviously a part of the presentation, but necessarily linked with safety: indeed, for French nuclear industry, reliability is sought for in order to guaranty the safety of the process and to prevent any diffusion of radioactive products in the environment.

Yet why speaking about nuclear safety? Because of nuclear production of course! Without any need and will to produce energy from nuclear power, the question of nuclear safety would not exist. This means that reliability and safety cannot be disconnected from production, and must be built taking into account the purpose of nuclear industry: producing energy.

These are the reasons why the three words, reliability, safety and production keep close to each other in this presentation title.

Nuclear production of electricity: a simple and marvelous idea from the scientific standpoint
Nuclear production consists in producing electric energy from nuclear energy. From the very simple idea which is the fission of atoms, warmness is obtained which is used to transform liquid (usually water) in gas under pressure for it to make a turbine turning. This turbine is coupled to an alternator which produces electricity.
From the scientific standpoint, this is a remarkable and marvelous technical and intellectual realization. This completion summons Nuclear Physics, Thermal Physics, Hydrodynamics, Hydraulics, Electrotechnics, Electricity, Materials Physics, Chemistry, Computer Sciences and Socio-psychological Science at least.

In the same approach, the conception of the industrial plant is based on a simple idea. The main loops are connected together to carry energy out of the core to the turbine connected to the alternator. The three loops are the primary loop with high pressure liquid water (155 bar, 304°C) in contact with the coil tubes, the secondary loop part liquid and part gas of water to make the turbine turning and thus the alternator, and a third loop as a cooling system of the second loop in order to reduce the vapor in liquid water to be re-injected inside the vapor generator. This third loop includes the tall aero-refrigerants making clouds of water over the nuclear plant. This basic conception description is presented on Fig. 1.

Unfortunately, the achievement of such a simple basic idea remains complex. When the primary loop is duplicated for a better efficiency, when are added safety and redundant loops to increase the safety level of the plant with differentiated pieces of equipment, and when you add to the Physics all the Chemistry in order to have

* This work has been presented at the conference of the *Aquares 49* network (now called *Aquarel 49*) which held on the 30th. January 2012 in Angers, France.

a better protection of the metal apparatus, you obtain a complex technical system.

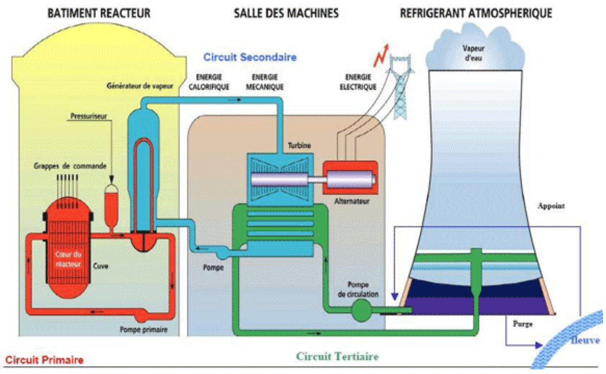

Fig. 1: Simple drawing presenting the three loops of the Pressurized Water Reactors (PWR) of French conception: the primary loop in red, the secondary loop in blue, and the third loop in green.

From the safety standpoint, basically three safety barriers are implemented to guaranty the confinement of the radioactive products and three loops to carry out the energy. For the Pressurized Water Reactors (PWR) of French conception, the three barriers are the fuel sealed metal tubes cladding, the heavy steel reactor vessel and the primary cooling loop, and the containment building.

And to make this complex technical system operate, you need women and men at work within an organization which is also complex. For example, a nuclear power plant like the one of Chinon (center France) with four reactors able to produce 900 MWe each, more than 1200 are needed permanently, and these people increase to the double during the maintenance periods which last several weeks per year for each reactor. It is clear that the complex technical system is transformed in a complex socio-technical system.

As we can see, from a basic simple idea of atoms fission, we obtain a huge industrial system operated by women and men. The questions of safety and reliability thus remain crucial: from the technical standpoints but also from the organizational and human standpoints. They are dealt with as soon as the plants conception, the operating period, and the dismantling.

How to learn from a no accident operating feedback?
Very few accidents have occurred for the world nuclear industry relatively to the amount of MWe produced and the number of operating years. Unfortunately, when such an accident happens, not only the operating staff is concerned by the consequences but also people leaving around the plant at a high level, and at a lower level, all the planet.

Nevertheless, conception of a nuclear plant is quite different from one country to another, even within the same country (like in Russia for example). It is the same for the safety policy of the country. This leads to the fact that the occurrence of a nuclear accident in a country is not easy to extrapolate to another. Thus, thinking that the 2011 Fukushima accident is an experience that must be used as an argument to stop everywhere with nuclear energy is a mistake: this would be equivalent to say that if one day a technical defect leads the Japanese Mitsubishi company to stop suddenly the use of their cars, this implies to stop the use of the French Renault cars. Of course, it would an aberration. This reasoning is valid for nuclear industry: the policy, conception, operating, environment, culture of French nuclear industry is so much different from the Japanese one that Fukushima accident cannot lead to the conclusion that French nuclear production of electricity must be stop.

Despite these important differences, the international feedback can be used by French nuclear industry to learn from accidental experiences. To illustrate this proposal, we shall restrain in this short presentation to the case of two items:

- The safety probabilistic studies.
- A multidimensional experience feedback (internal or external).

The safety probabilistic studies, or Probabilistic risk assessment (PRA), are a systematic and comprehensive methodology to evaluate risks associated with a complex engineered technological entity (such as an airliner or a nuclear power plant). Risk in a PRA is defined as a feasible detrimental outcome of an activity or action. In a PRA, risk is characterized by two quantities: the magnitude (severity) of the possible adverse consequence(s), and the likelihood (probability) of occurrence of each consequence.

For this aim, the fact that the French nuclear fleet is homogeneous is a real strength: a difficulty on one reactor gives at once an adjustment for all the others.

The multidimensional internal experience feedback is based on:

- Systematic event analysis for each nuclear power plant. Concerning this item, it must be noticed that EDF is the only nuclear operator in the world adding a level 0 (zero) on the International Nuclear Event Scale (graduated from 1 to 7) in order to declare and give to the national regulator all details even for safety event with no importance from the point of view of safety.

- Shared data banks.
- Statistical trend analysis.
- Injection of all the results produced by the above items into the safety probabilistic studies.
- Use of all the results produced by the above items to foster the experience feedback (Fauquet-Alekhine, 2012a).
- A permanent re-questioning of the organization robustness (for example, each plant re-questions some decision making process through an observatory for safety, radioprotection, environment, production).

Concerning the external aspect, the experience feedback analysis for the EDF company leans on:

- The feedback of important nuclear accidents.
- The accidentology, analyzing the important accident analysis, including all industries in every country.
- A permanent benchmarking and look-out.
- A permanent re-questioning of the socio-technical system.

We shall thereafter develop the external aspect of the multidimensional experience feedback.

The feedback of important nuclear accidents

The Three Miles Island accident (USA, 1979) led to optimize the Human-Machine Interface with a strong belief in the all-technology control. Focusing on this all-technology control has yet shown its limits and the Tchernobyl accident (Ukraine, 1986) has led to conclude that taking into account the HF aspects is thus quite important. This has notably pointed out that the Human contribution to the accident occurrence could be significant. It gave rise to the realization that the process safety could not be only or at least mainly based on technical automatic controls. The place of Human inside the process had to be reconsidered. This industrial catastrophe has shaked the world of risky industries and has led all decision-makers to seek work axis to reinforce the socio-technical systems and make them safer (Amalberti, 1996 et 2001; Reason, 1993 et 2008). For the French nuclear industry EDF, one of the main points has been to development a HF policy, with the creation of the job on each nuclear power plant: Human Factors Consultant. The HFC must help to take into account the HF dimension at work (Fauquet-Alekhine, 2012b).

More recently, the Fukushima accident has led to several analysis among which the own one of EDF. Within a few months, corrective actions have been identified and implemented. For example, despite the important differences between the Japanese and French socio-technical systems, the EDF analysis has pointed out that in case of a sudden problem with the same intensity than in Japan (whatever its nature), a French nuclear power plant could need a fast logistic rescue support. For this aim, the FARN has immediately been created. The FARN is "Force d'Action Rapide du Nucléaire" (Fast Task Force of the Nuclear) able to go beyond the conventional means in a short time (Fig. 2).

Accidentology

One team of the Research & Development laboratories of the company is devoted to this topic. Major accidents of any industrial fields in any countries are analyzed in order to understand the causes and to study the analytical method applied by the investigation board in charge of the inquiry.

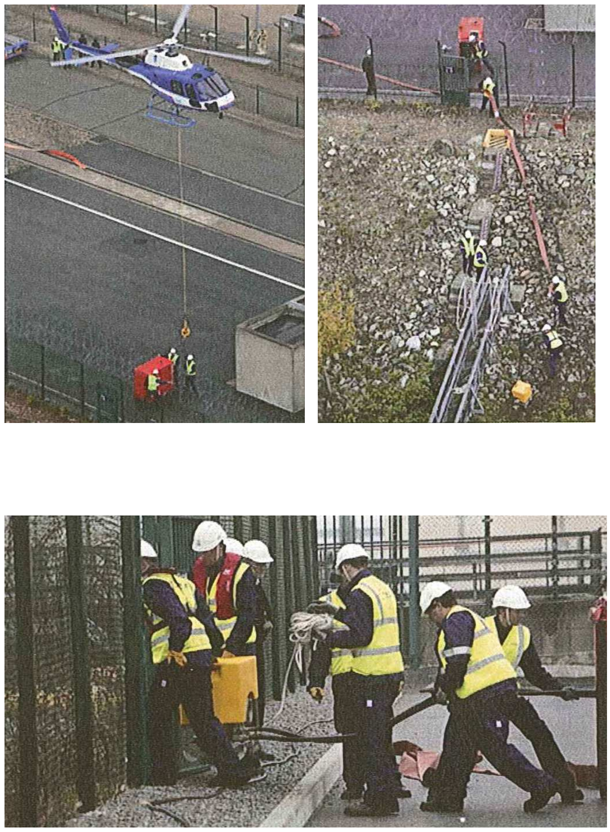

Fig. 2 a, b, c. Pictures of the first exercise of the FARN took place in the French NPP of Cruas in October 2011.

To give an idea of what can be done, we reproduce here the abstract of a communication concerning the subject and recently presented by researchers of this team to the society of French language ergonomy (Dien & Fucks, 2011):

"Industrial risk management is a major challenge for companies. It is based in part on the benefits of learning from experience, lessons learned from the events. The

problem is therefore moved to the quality of the analyses of event. From an exemplary investigation of a rail accident, we will suggest that the ergonomic approach tools are essential for understanding the causes direct and immediate of the occurrence of an event but that the root causes apprehension convene from other social science concepts that are not yet integrated into the usual steps in ergonomics. In other words the ergonomic approach which is essential for the management of industrial hazards must also, in this area, incorporate the results of other approaches that are now less familiar."

The permanent benchmarking and look-out

One of the recent productions of the benchmarking is the Human Performance Program implemented since 2006. A large benchmarking has been done (different countries, different industries) to identify especially: i) how can progress a safe industry by avoiding minor events? ii) what helps a worker to avoid minor events? The Human Performance Program is situated within the framework of the Human Factor policy of the company and involves organization, interveners and management of French nuclear power plants with the main aim to enforce nuclear safety. It consists of several items among which one concerns the workers in the field for who six Human Performance tools (HP tools) have been required for any intervention on the equipment. These HP tools are expected to soon be part of the professional practices of any workers of the French nuclear industry. They focus on the realization phase of interventions and make the link with preparation phase and feedback phase (Fig. 3).

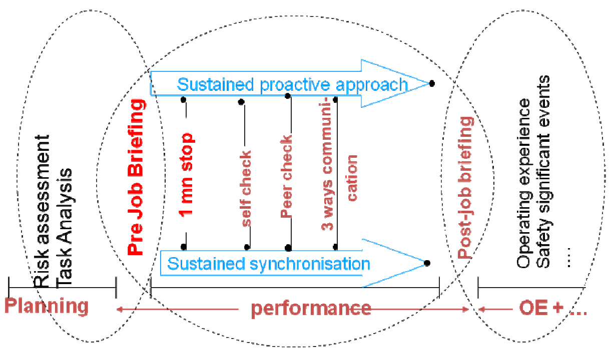

Fig. 3: The six Human Performance tools expected to be part of professional practices, presented according to the three work activity phases: planning, performance, operating experience.

The HP tools can be described as follows (Theurier, 2010):

- The Pre-job Briefing: located after the preparation of activity (including risk analysis) and its appropriation by the interveners, and just before the activity itself, the Pre-job Briefing is a specific phase of mental preparation and coordination for the interveners: sharing of perception, implementation of key risks in working memory, …

- The Take a Minute: located on the workplace and just before its start, it asked workers out of the urgency of action for analytical look at the work environment: am I on the right unit? the right track? the right equipment? do I have a risk of accident? … The "Take a Minute" is also used in case of interruptions or progressive drift of the situations outside the planned framework.

- Self-check: it permits one to avoid the usual global analogical way of reading. It asks analytic reading (read aloud and point the finger) of the identifier on the procedure and its corresponding tag on the equipment before implementation of an action.

- Peer-check: it asks, in addition to the self-check, another person to verify the coherence between the intention announced and the draft of the action to complete before it starts. It helps strengthen vigilance.

- The Debriefing: it definitely finished an activity by expressing difficulty and facility encountered in the action and the "innovative" means in place to achieve the result. It is a point of engagement inside a loop of progress for future interventions.

- Reassured communication or 3-way communication: it allows to ensure that information has reached the consciousness of the intervener while he was focused on his/her activity. The addressee must repeat the information received and the addresser must confirm the accuracy of the repetition.

Note that none of these practices (excluding the content of the debriefing) is expected to be written. This avoids any "administrative" drift.

Quantifying the results induced by such actions is difficult because they are always part of an action plan. What can be rated is the result of all of these joint actions. To give just two indicators, since 2006, i) the number of reactor automatic scram for French nuclear power plants has been reduced by more than 20%, which is considerable, ii) the number of events involving a punctual error has progressively and constantly diminished as illustrated by the graph on Fig. 4.

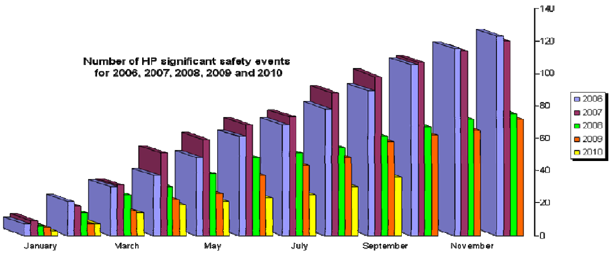

Fig. 4: Variation of the number of events involving a punctual error of workers since 2006.

Another recent production of the benchmarking is an organization of the experience feedback and its integration by the PAC (Fauquet-Alekhine, 2012a): « le Programme d'Action Corrective », inspired by the American CAP (Corrective Action Program). The PAC is based on a frequency of analysis of the input findings in a computer database, and a closure findings-analysis-actions-results-findings. Identification of the experience feedback and the material of which it is made up are done via the findings every day. The consolidation of data entering is made the day after to verify the characterization of the findings and to ensure homogeneity of these characterizations. This point is fundamental because if there is heterogeneity at this level, trend analysis and statistical analysis are generally impossible. Then, the findings are prioritized, posted weekly and kept in check weekly and monthly. The aim is to appreciate whether the findings are archived for memory without action, or for simple action, or for specific analysis. The whole gives rise to trend analysis.

Quantifying the results of such action is not yet possible because of the very recent character of this action.

The permanent re-questioning of the socio-technical system

This state of mind and the consecutive organization is fundamental to maintain the socio-technical system in a permanent progress loop. All domains are concerned within the company and thus examples are numerous. We shall take just one example linked with what was exposed above following the Tchernobyl accident. The consecutive Human Factors policy has been re-questioned several times. In this framework, the Human Factors Consultant position has been re-defined. If we have a look at the history of the job, since the beginning, six steps at least can be identified:

- 1993: the Human Factors Consultant (HFC) position has been created within the company.
- 2000: the recruitment for this job has been adjusted according to the first feedback years.
- 2002: the profession has been included within a specific management of the company jobs and the profession guidelines have been published.
- 2008: jointly with industrial partners, a professional master has been created in order to offer newcomers in the job an academic background adapted to the need.
- 2010: because of economic context changing and staff renewal, and thus human factors context changing in the company, the job profile has been revisited thanks to all the HFC of the nuclear fleet and their contribution has led to an adjusted re-writing of profession guidelines.

Conclusion

All what is presented here shows that "no accident on the nuclear fleet" does not mean "no re-questioning". On the contrary, it shows how the EDF company holds the "permanent re-questioning" as the meaning of "no accident on the nuclear fleet".

Especially, referring to Bird's pyramid (1966) reproduced on Fig. 5 obtained through a survey of 1,700,000 accidents and based on Heinrich's work (1931), the systematic event analysis policy concerns all levels of the pyramid: the upper part is investigated through foreign events, and the bottom part is analyzed according to the internal experience feedback improved and reinforced periodically according to the re-questioning of the socio-technical system and to the benchmarks and permanent look-out. In agreement with Bird's findings, the policy consists to correctly improve accident prevention, which implies to properly identify weaknesses in the organizational system that have potential for loss.

Fig. 5: The Bird's pyramid (1966) showing that there exists 1 major accident for 600 minor events.

This contributes to the guaranty of a safe operating of the French nuclear reactor fleet. What must be kept in mind is that the zero-failure does not exist as it is an utopia, but we can seek the zero-consequences.

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Chapter II

Human Performance

Improving simulation training: anesthetists vs nuclear reactor pilots

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http//hayka-kultura.com/larsen.html

Abstract

For many years, stress has been shown by researchers to be both a source of performance and a source of cognitive disorders. Studies have shown how to measure some of those parameters identified to be closely associated with the occupational stressed state of subjects, involving heavy medical facilities requiring specific devices and specific software for analysis. We have here elaborated a simple protocol requiring basic metrology and simple straight data analysis, qualified through specifics tests and showing a Yerkes & Dodson (1908) relationship between stress and performance. Application for reactor pilots and anesthetists training sessions on simulator has led to identify cognitive disorder zone during training and suggestions have been made for improvement.

1. Introduction

For many years, stress has been shown by researchers to be both a source of performance and a source of cognitive disorders. Getting information about the kind of influence of stress in a work activity has appeared very useful to be able to work mainly under the positive influence of stress. For this aim, qualitative considerations help, but the best is to maintain quantitative approach because of the objectivity. Many works have been done in order to make the link between stress and physiological parameters in a quantitative approach, and studies have shown how to measure some of those parameters identified to be closely associated with the stressed state of subjects. Nowadays, some medical facilities are available to do such investigations, which require specific devices, metrologies, and then demand specific software for analysis (see section 2). At each step, specialists are necessary. But for some industrial contexts, such a complicated organization cannot be applied, for a matter of time and money, while it would be of great interest to have better knowledge in specifics cases: classic training session, training on simulator, evaluation, crisis management…

Here we are involved in the elaboration of a simple protocol, requiring basic metrology and simple straight data analysis, to be used on training simulators (we shall propose the comparison of anesthetist and nuclear reactor pilot cases) by the trainers who are not necessarily experts in medical researches. We are interested in performance analyzed versus stress estimation. Different relationships between the occupational stress and the performance have already been obtained by others (for example see the review of Staal, 2004; and also the work of Broadhurst, 1957; Hancock et al., 2002). The final aim is to appreciate whether trained people are in a cognitive disorder zone or not.

2. Materials and Methods

This study deals with a specific kind of mental stress, the short term occupational stress, versus performance of workers. On the contrary of sophisticated metrologies and elaborated software which need, thereafter, a careful data examination to be sure of the conclusions (Montano et al., 2009; Rohleder et al., 2009; Schubert et al. 2009; Bailon et al., 2010), we aim at a simple solution based on heart rate. Preliminary tests have shown that relevant parameters (measured using a Polar FS2c) would be, for this kind of stress, the mean heart frequency (HR_{mean}) and maximum heart frequency (HR_{max}) as shown before by others (see for example Schubert et al., 2009). The following graph (Fig. 1) shows how the heart rate changes with the different steps of the test: for each question identified, the person starts to read, the person reads, thinks, begins to write, writes and thinks, turns the page and starts to read …

The heart rate always reaches the highest value in the initial stage of dealing with the question, either while reading, or when beginning to write. Then, during the treatment, heart rate decreases, and increases again if the subject hesitates (case of "stop writing" for example).

The record lets us think that, to have pertinent heart parameters concerning stress, we must be interested at least by a mean value and a max value.

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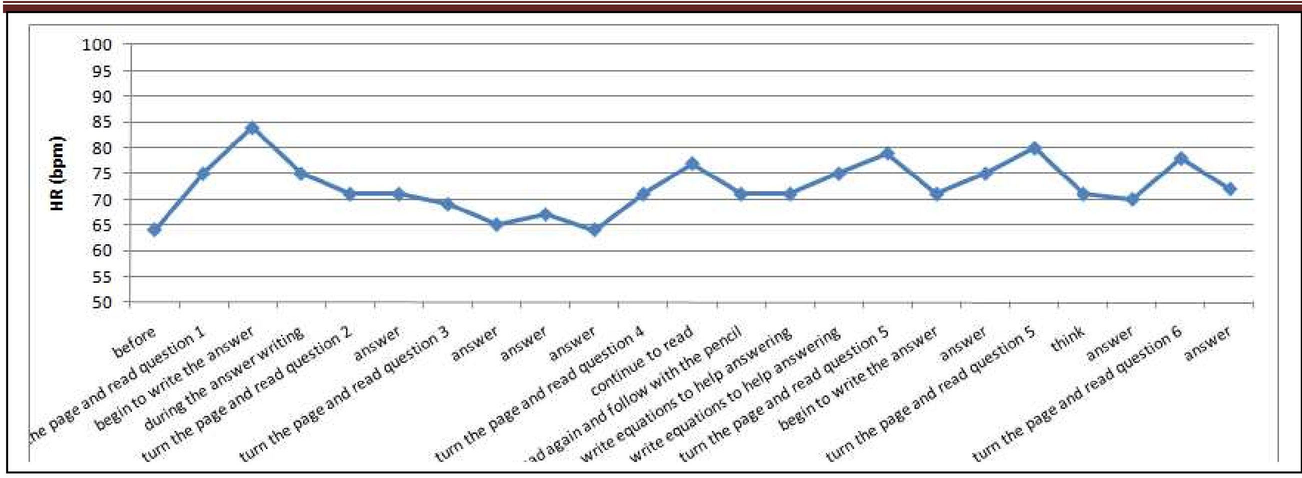

Fig. 1. HR changes during the Stress-test according to the actions done by the subject.

2.1.The Stress-test

A Stress-test made up of 12 questions has been first used to qualify the protocol and devices. It has been taken by French subjects (*N*=18; 50% male) healthy, same kind of academic background, about 25-35 yo, in two different conditions: No Stress and Stress Conditions. These two expressions are used to differentiate the test conditions, knowing that the first one refers to stressless conditions compared to the second one in which stress factors have been reinforced on purpose. For example, one of the stressful factors included in the Stress Conditions while not used in the No Stress Conditions of the Stress-test is the clepsydra. The clepsydra was said to bound the activity time length (Fig. 2) in a very specific manner; it was specially developed for the purpose. The clepsydra presented three holes in the upper part of its bottom receptacle and the subject was told to be expected to finish the task before the water would flow out of the holes on his/her desk, as the experiment was conducted inside the subject's work office. Analysis has shown that this factor was highly stressful.

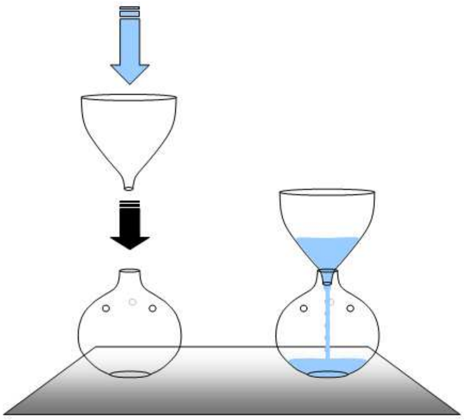

Fig. 2. The clepsydra designed by Fauquet-Alekhine for use during Stress-test taken by a subject who must perform a given task (Fauquet-Alekhine et al, 2011). The two receptacles of the clepsydra are put together and the water flows from the upper part to fill the bottom part until the holes are reached. Then the water will flow out of the clepsydra.

2.2.Elaboration of the Stress-test conditions : the 3-level qualitative scale

To elaborate the conditions, a 3-level qualitative scale (3-LQS) has been developed and applied based on work activity analysis, using stress variables within a 3-D source space (context, request or job demand (excluding context), subject's characteristics) close to previous works (McLean, 1974; Karasek et al., 1990, 1998) linked to a 3-D symptoms space (physiological, psychological, behavioral) as detailed in Fauquet-Alekhine (2011, 2012a and especially 2012b): we made the demonstration that short term mental occupational stress could only be correctly modelized if the stress consequences were taken into account.

The 3-level qualitative scale has been built on the basis of an a priori task analysis in order to identify the parameters involved or not in the stress. For this aim, the work activity analysis has been conducted in two steps:

- a macro approach identifying macro-variables to describe the stress conditions,
- a refined description of those macro-variables with variables to be identified, and an evaluation of these variables as parameters contributing to the subject's stress.

Proceeding with two steps was better: it helped the analysis to focus observations on each field bounded by a macro-variable, made the analysis more efficient by focusing then on each one, and led to a more efficient description and evaluation of the variables.
The following Table I describes the macro-variables and gives the link with their respective stress dimensions.
Based on the studies done in the field of stress at work (see previous section) and our own experience, 8 macro-variables have been retained and named to describe and manage the conditions of short term occupational stress.
It must be kept in mind that it would be different for others cases of stress: others parameters come into account for long term stress or if the stress is not principally linked to the job.

These macro-variables can be used to widely describe short term stress induced on the subjects in work situations, and match the parameters used in other studies to describe stress conditions. In this study, each macro-variable has been broken down into several variables that will be described below; these variables are a refined level of description and have the possibility to vary from a no stress level to a stressful level. For example, considering the macro-variable "environment", we might be in a case for which the variable "color of the room" is relevant: a soft colored room is rather relaxing, while aggressive colors will be supposed to stress people.

Of course, as reminded in the NASA review of Staal (2004), "stress" is a term that can be applied to any demand to a system. This means that "any task that requires mental resources qualifies as a stressor". This must be understood as: "we ask, we stress", but we stress at a different intensity according to the specificities of the request and all the other variables linked with the request. Thus, as explained before, we must not think the "no stress level" of a (macro)variable as a level characterizing an absence of stress, but it must be understood as the low limit of the (macro)variable which could potentially be reached.

Table I. Identified the macro-variables for short term occupational mental stress during Stress-test and training sessions.

Macro-variable	**source dimension concerned**	**Description of the macro-variable**
T: task	job demand dimension context dimension	Describes the task which has to be done, level of feasibility, task goal, organization and means, time length.
D: documentation	context dimension	Describes the quality of the documents used by the subject to do the task.
P: place	subject's characteristics dimension context dimension	Describes what means the place for the subject, regardless to the following activity (association with some jobs done there before in such a place; if unpleasant activities, then stressful).
SS: social support	context dimension	Describes all relationship with people link with the task during the job.
S: subject	subject's characteristics dimension	Describes feelings and states of the subject which are known.
M: metrology	context dimension	Concerns the metrology which is necessary used for the present experiments.
E: environment	context dimension	Describes environmental conditions.
AD: additional factors	all dimensions	Concerns some factors which can be added according to the situation.

Each macro-variable is made up of variables, which are evaluated as a first approach on a 3 unit scale:

- no stress: it seems to have relaxing or reassuring character, and it will likely be significant during the activity, for most of the subjects,
- medium : it seems to have neither any stressful character, nor relaxing properties, and it will probably be stable during the whole activity, but can significantly vary from one subject to another depending on the subject themself,
- stress: it seems to have stressful character, and it will likely be significant during the activity, for most of the subjects.

These three levels are used to describe a priori the effect of each variable on the psychological state of the subject in a qualitative approach. Evaluating these variables according to this qualitative scale has helped to build the two kinds of conditions of the Stress-test as a first approach. The evaluation of these variables can be refined later, but the only way to refine them is to make the subjects answer an adapted perception questionnaire of stress including these variables. During the conception of the task, it is difficult to be more accurate than this 3-level qualitative scale: at this stage, we can only postulate when the variable intensity will rather be relaxing, neutral (medium intensity) or stressful.

It must be noticed that the 3-level qualitative scale is a major tool, and works according to simple rules. It is of great importance to remark that the identification of the (macro)variables, their description or their label, the accuracy of the way they are refined, are not as important as the exhaustiveness of the whole. Here, exhaustiveness means that all the relevant parameters of stress must be taken into account within the (macro)variables. Identification, description and label, can be done differently from one work analyst to another for one given activity; the main point is to build a pertinent 3-level qualitative scale and have a sufficiently refined analysis of the activity or at least of the task to reach a right evaluation of each variable level. The rules for the 3-level qualitative scale are: exhaustiveness combined to pertinence, and correct level evaluation.

To illustrate these rules, we shall give short examples:

Exhaustiveness and pertinence lead to the identification of variables: we wrote that it can be different from one specialist analysis to another, and that it will not spoil the final results. This is true provided that exhaustiveness and pertinence will both characterize this identification. For example, two analysts can think about tool ergonomy of the work activity. One of them will think that it concerns the macro-variable Task, the other the macro-variable Environment. Here, no matter which macro-variable includes the ergonomy, the main thing is to include it within the scale if it concerns the activity with a relevant link. But is it really relevant? If not, we must not hesitate to banish it from the scale which must be exhaustive but meaningful, not overloaded. We can illustrate it with the application to the case of the task built for the Stress-test: subjects have taken the test in their job office; they will have to sit on their daily chair, and work with a pen, reading papers. In this case, ergonomic problems do not occur: on the 3-level qualitative scale, ergonomy is considered irrelevant because it will have neither any significant stressful character, nor significant relaxing properties (nothing is especially done for this purpose), and it will be stable during the whole activity, and so from one subject to another.

Exhaustiveness does not mean that every parameter of stress must appear on the scale: it must be relevant according to the activity studied.

As we can see on Table 1, the (macro)variables concern both the 3-D spaces described in the previous section (source and consequences), but can be only described a priori inside the 3-D source space.

The results of the 3-level qualitative scale giving the a priori description of the Stress-test conditions are described in the following Tables 2 and 3. It has been obtained by refining the macro-variables into variables which description is done here after, for which we explain two extreme states concerning respectively No Stress and Stress conditions, using the 3-level qualitative scale.

Table II. Identified variables for short term occupational mental stress during Stress-test in No Stress Conditions and evaluation on the 3-level qualitative scale

Case of No Stress Test

Dimensions	no stress	medium	stress
T task level : easy - difficult	1	1	
T task level : known - difficult or unknown		1	
T task objective : clear - undefined or fuzzy	1	1	
T task means : adequat - none or insufficient		1	
T task organization : adapted - not sufficient or not adapted or new		1	
T task : length : short - long		1	
T task time constrains : without - with	1	1	
T briefing task : helpful - useless	1	1	
D doc : helpful - erroneous		1	
D doc : understandable - complex	1	1	
P place : linked with easy task - linked with difficult task	1	1	
P place : known - unknown	1	1	
SS social support : peer - subordinate		1	1
SS social support : helpful - agressive	1	1	
SS social support : eval.with consequences - eval. with no consequences	1	1	
SS social support : quiet - disturbing	1	1	
S subject competence perception : good or upper level - low level	1	1	
S subject physical state : good - bad		1	
S subject psychological state : good - bad		1	
S subject risks perception for others : with - without		1	
S subject self risks perception : with - without		1	
S subject autonomy peception : possible - impossible	1	1	
M metrology : none or invisible - disturbing		1	
E environment sound : calm - noisy	1	1	
E environment view : not agressive - agressive		1	
E environment smelling : normal - heavy		1	
AD additional factors = Ant et Post factors APF		1	
AD additional factors : others			
description of additional factors			clepsydre

Table III. Identified variables for short term occupational mental stress during Stress-test in Stress Conditions and evaluation on the 3-level qualitative scale

Case of Stress Test

Dimensions	no stress	medium	stress
T task level : easy - difficult		1	1
T task level : known - difficult or unknown		1	
T task objective : clear - undefined or fuzzy	1	1	
T task means : adequat - none or insufficient		1	
T task organization : adapted - not sufficient or not adapted or new		1	
T task : length : short - long		1	
T task time constrains : without - with		1	1
T briefing task : helpful - useless		1	1
D doc : helpful - erroneous		1	
D doc : understandable - complex		1	1
P place : linked with easy task - linked with difficult task		1	
P place : known - unknown	1	1	
SS social support : peer - subordinate		1	1
SS social support : helpful - agressive		1	1
SS social support : eval.with consequences - eval. with no consequences	1	1	
SS social support : quiet - disturbing		1	1
S subject competence perception : good or upper level - low level	1	1	
S subject physical state : good - bad		1	
S subject psychological state : good - bad		1	
S subject risks perception for others : with - without		1	
S subject self risks perception : with - without		1	
S subject autonomy peception : possible - impossible		1	
M metrology : none or invisible - disturbing		1	1
E environment sound : calm - noisy		1	1
E environment view : not agressive - agressive		1	
E environment smelling : normal - heavy		1	
AD additional factors = Ant et Post factors APF		1	
AD additional factors : others			1
description of additional factors			clepsydre

As said before, the appreciation of the level is made by the specialist, a work analyst, from his/her own point of view according to the way s/he built the conditions for the parameter to induce stress or not, except for those of type "S subject". For example, if the task is made for a subject in agreement with his/her skills and competence, according to what such a subject is expected to know and to be able to do, the specialist will identify the task level as "easy", which will match "no stress" on the scale. On the other hand, if the specialist identifies a task which cannot be done easily according to the knowledge and competence of the subject, s/he will identify the task level as "difficult", which will give "stressful" on the scale. In the case of the task is concerned by the variable, but for which no a priori estimation of effect on the potential level of stress is possible, then the level chosen is "medium".

2.3.Perception of Stress

The perception questionnaire of stress used for this experiment (the Post Disorder Inventory or PDI questionnaire) has been elaborated earlier in order to obtain a quantitative measure of the level of distress experienced, tested by several including in its French form (see Jehel et al., 2005 and 2006). This questionnaire has been chosen after having studied several questionnaires for self-rating of stress, established and scientifically tested. The Job Content Questionnaire of Karasek has not been retained here because, even if the variables are watched through the items, some questions do not concern the Stress-test or the training sessions, and some variables, which are relevant to be asked, are not investigated by the questionnaire. The Cohen's Perceived Stress Scale (PSS) (Cohen et al., 1983) as the more recent Work and Well-Being Questionnaire (Kilminster et al., 2007; Bridger et al., 2011), concern the long term stress and thus is not adapted to this study. The State-Trait Anxiety Inventory (especially the STAI form Y-A self-rating the subject's anxiety state) developed by Spielberger (1983) has not been used because it measures anxiety with too few reference to exogene parameters.

For the present study, the PDI questionnaire was used immediately after taking the test. The subjects were asked to answer each question according to a 5 levels Likert type scale: not at all, a few true, rather true, very true, extremely true. The questionnaire was used in French (see appendix). The translated questions are listed below:

01-I felt helpless to do more
02-I felt sadness and grief
03-I felt frustrated or angry I could not do more
04-I felt afraid for my safety
05-I felt guilt that more was not done
06-I felt ashamed of my emotional reactions
07-I felt worried about the safety of others
08-I had the feeling I was about to lose control of my emotions
09-I had difficulty controlling my bowel and bladder
10-I was horrified by what happened

11-I had physical reactions like sweating, shaking, and pounding heart
12-I felt I might pass out
13-I thought I might die

2.4.The protocol

The protocol applied to generate the test conditions is described in Table IV, each column referring to a given condition. Each line of Table IV describes one step of the protocol and the difference between the two conditions can be easily understood.

Table IV. Comparison of the two Stress-test conditions.

Stress Conditions for the Stress-test	**No Stress Conditions for the Stress-test**
The researcher presented the test as a set of twelve questions to be answered as fast as possible, in a time presented as limited by the clepsydra that will be charged with water (Fauquet-Alekhine et al., 2011). It is explained that the clepsydra has holes that will pour water on the desk if it is not stopped soon enough corresponding to the time the subject will finish the test: thus, the subject must answer fast, and no information is given concerning the given time.	*The researcher presents the test as a set of twelve questions to be answered without any limit of time. Nothing is said concerning the clepsydra as it is not used.*
The researcher informs the subject that, during the test, the monitor will be worn on the wrist, and that it will give out a beep when the heart rate rises over a given threshold.	*The researcher informs the subject that, during the test, the monitor will be on the table in order the make some measurements of heart rate. Nothing is said concerning the beep as it will not be used.*
The subject is asked to be involved in the test until the end: if s/he accepts to begin, s/he engaged her/himself to achieve the test. The subject is said "alone": it means s/he will not have any possibility to ask any question during the test. If a question seems too difficult, s/he can go further, then come back to this question, or leave it. When the subject decides that s/he reaches the end, the heart rate monitor is stopped.	*The subject is asked to be involved in the test until the end: if s/he accepts to begin, s/he engaged her/himself to achieve the test, but subject is not "alone": it means s/he will have all possibility to ask the researcher any question during the test. If a question seems too difficult, s/he can go further, then come back to this question, or leave it. When the subject decides that s/he reaches the end, the heart rate monitor is stopped.*
In both cases, the mean and maximum heart rate at rest sitting are checked.	
Before beginning taking the test, the researcher sets the monitor at a low threshold to produce a beep very quickly. It means that the parameter value will be chosen according to the maximum heart rate just measured at rest. The monitor is put on the subject's wrist. Usually, a few seconds after beginning the test, the monitor beeps.	*The researcher leaves the monitor on the table. It will not do any beep.*
Then the test begins, and water is poured inside the clepsydra: water begins to flow and makes very rapidly the noise of a liquid stream hitting a surface of water.	*Then the test begins.*
Meanwhile, the researcher paces up and down in front of the subject.	*Meanwhile, the researcher takes a sit close to the subject, reminding that he is ready to answer any question.*
During the test, the water inside the clepsydra stops just under the holes: the quantity of water has been calibrated in order not to wet the desk. The researcher then says: "I did not put enough water, but anyway, you must hurry up"; he orders it severely. Usually, it happens before question #7.	*The researcher is just waiting for some questions. If there is no one, he reminds gently to the subject this possibility.*
Meanwhile, the researcher keeps on pacing up and down in front of the subject.	*Tthe researcher is just waiting for some questions.*
When the subject reaches the question #10, the researcher says "now, hurry up, please". As before, he orders it severely.	*During the test, the researcher is just waiting for some questions. If there is no one, he reminds gently to the subject this possibility.*

To avoid any bias due psychological interferences as observed for example with the Stroop effect (see studies of Mathewson et al. (2010) which concern performance of a pictorial Stroop task), the questionnaire presented is written in black ink on white paper.

2.5.The Stress-test questionnaire

The Stress-test is made up of 12 questions. A performance coefficient, based on the right answers given by the subject, is calculated for each subject. This performance coefficient is related to the subject's stress, according to lots of research works. Subjects must answer all the questions, but only 9 questions are used for analysis because 3 of them involve the cultural affinities or the ability to calculate (they are used in the test in order to make the subject think not only about logical problems). For example, somebody who is used to traveling in Africa or America will have more problems to know in which country is Minsk than somebody traveling in ex-soviet union every year. Concerning calculation, somebody who makes mistakes can nevertheless reach the right results, which is not necessarily a matter of stress.

The test itself has been designed to be taken in 5 to 15 minutes. Considering that we must spend time with the subjects to present the test at the beginning of the meeting, and after the test we ask the subjects to fill questionnaires, the whole time spent with the subjects is about 30 to 45 minutes. As we ask them to take the test on their place of work, i.e. their office, (in order to fix this environmental factor of the task variable), it is welcome to make this time less than one hour (less than one hour is acceptable; if more, we should take too much of their time and subjects would not accept the test).

The questions asked for the Stress-test are the following types:

1) Link together numbers on two lists of six numbers each (on one side, one has no correspondence, and another is written twice).
2) Raven's progressive matrix: 3 series of 3 patterns, one missing to be found on the last line.
3) Logical series: for each of the 3 series, find the next value.
4) Calculation test: a temperature is increased twice by 10%, so finally it has increased by 20% of the initial value - right or wrong?
5) Cogs: one of them turns in a given way, which way does the last one turns?
6) Cogs: same task than #5 but a bit more complicated.
7) Perceptive test of reading: read the 3 lines of capital cursive text and find how many 'V' are in the text.
8) Language test: link French word with corresponding foreign word (5 words of each).
9) Language test: encircle the odd word out among 5 foreign words.
10) General culture test: link towns with corresponding countries (5 of each).
11) General culture test: link towns with corresponding countries (5 towns, 7 countries, and some of them have no link; 1 town and 3 countries).
12) Speed test: put in alphabetic order 12 letters presented on one line, in capital letters (one is written twice).

Among these items, #4, 10 and 11 are not used for the calculation of the score because, as said above, they involve the cultural affinities or the ability to calculate.

2.6. Application to nuclear reactor pilots

Analysis of French nuclear pilots training ($N > 100$) is done below using the qualitative scale. This is done in order to evaluate the appropriateness of learning conditions (concerning the effects of stress) with the possibility of the trained people to find appropriate conditions of learning.

The purpose is to use the 3-level qualitative scale a posteriori for simulation training analysis, while it has been done a priori for the stress-test.

The training of French nuclear pilots is scheduled in 5 steps, involving 123 days spread over 15 months, both in room and on simulators. The training in room consists of conceptual and theoretical knowledge, and of description of the installations and materials. The training on simulators consists of two parts, one on the simulator itself, and one in room to discuss what has been done during the simulated situation; 3 hours are devoted to each part.

There are three kinds of simulators: part simulator, full scale simulator, and virtual simulator. The full scale simulator reproduces the full control room of a reactor, with a refined simulation of the physical parameters of the process. The part simulators are parts of the full scale simulator; they are used to focus on a specific part of the piloting system; for example, one of the part simulators concerns the feeding-extracting system of the process (RVC mini simulator). The virtual simulator consists of computers performing software reproducing physical parameters; the installation is designed on the screen, and water and coil are visible inside components; values of the physical parameters are shown according to the process in progress.

The five steps of the French nuclear pilots training are:
CFTR: Conduite Formation Théorique Réacteur à Eau Pressurisé
(Theoretical training for Pressurized Water Reactor)
COSN: Conduite en Situation Normale (Operating in normal situation)
COSP: Conduite en Situation Perturbée (Operating in disturbed situation)
CAPE: Conduite en Approche Par Etat (Operating in accidental situation)
CRSN: Conduite Retour aux Situations Normales (Back to operating in normal situation)

Their characteristics are described in Table V.

Table V. Description of each step of the training cycle for French nuclear reactor pilots.

Training type	**description**	**room training**	**simulation training**
CFTR (60 d. distributed on 6 m.)	Understanding the industrial process from a technical and theoretical standpoint	10 w. (by a 1 or 2 w. periods)	Part simulators (3 types, 1 w. each) + full scale simulator (2x1w.)
COSN	Operating in normal situation: watching in control room understanding piloting in control room	1 w.	full scale simulator (by 1 w. period)
COSP	Operating in disturbed situation: watching information in control room diagnostic and decision applying actions control	1 w.	full scale simulator (by 1 w. period)
CAPE	Accidental situation: trusting procedures understanding procedures structures and actions applying procedures	3 d.	full scale simulator (5x1w.) + virtual simulator (3x1w.)
CRSN	Back to operating in normal situation: reminding the COSN adapting training to the pilots'needs specific plant feedback	0	3 d.

(d = day; w = week; m = month)

The four first steps are closed by an evaluation. On the chronological scale plotted below, it happens after about 6 months, 8, 10 and 14 months.

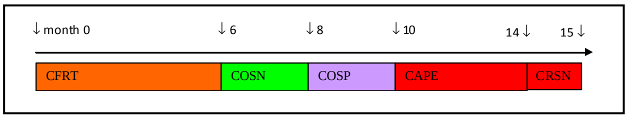

Fig. 3. Chronological cycle of French nuclear reactor pilots' training.

To rate the state of stress evaluated with the 3-level qualitative scale, we introduce the relative stress balance. It is calculated by doing the difference between stress and no stress variable, normalized by the number of variables potentially involved in the activity as stress or no stress variables. Then, we compared to the results obtained by the futures pilots trained on the French nuclear plant of Chinon during a given 15 months training cycle. For this aim, the compiled data concerning 2010 and involving more than 100 subjects have been analyzed.
It is important to notice here that the use of the 3-level qualitative scale has been applied independently of the results data analysis, to avoid any influence of the results on the scale appreciation.

2.7. Application to anesthetists training

After qualification of the protocol and device with the Stress-test, applications have been done to full scale simulation trainings for French anesthetist residents in a Paris district hospital (N=27) using the 3-LQS and physiological measurements.

Students were involved in a one day training session in operating theatre, and training was performed the whole week (5 days). It means one different group of about 6 students was received every day. At the end of the week, 27 French students have been trained, played different role depending on the scenario.
Four different scenarii were used per day (less than one hour each), and 3 students were training together per scenario, each scenario (about 30 minutes) followed by a debriefing session (30 to 45 minutes).

The participants of the simulated situation for a scenario were:

- 3 students playing the role of physician, nurse, and help,
- 1 physician trainer, playing the surgeon,
- 1 physician trainer piloting the simulator.

The scenarii were clinical cases involving only one dysfunction (no cumulative cases). The 4 scenarii were:

- Asphyxia related to post-operative cervical hematoma,
- Local Anesthetics intoxication,
- Peroperative third degree auriculoventricular block,
- Peroperative respiratory arrest related to injection of myorelaxant drug.

3. Results & discussion

3.1. The Stress-test experiments

Using the 3-LQS of stress, two conditions of the Stress-test have been built up, No Stress and Stress Conditions, for which the following radar graphs show the obvious difference expected (Fig. 4 a & b).

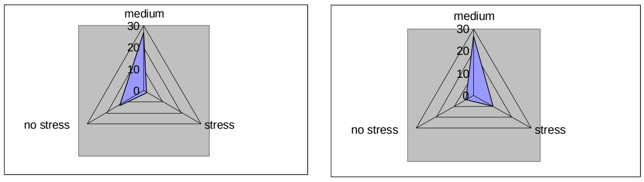

Fig. 4 a & b. The 3-LQS evaluation of the Stress-test conditions.

In order to verify whether the heart parameters can reflect the state of stress as exposed by others and reminded above, we have done a modal analysis of the mean heart rate, HR_{mean} , and of the maximum heart rate, HR_{max}.
This modal analysis has been done according to modes defined as follows, expressed in bpm :
[-inf; 50[, [50; 65[, [65; 80[, [95; 110[, [110; 125[, [125; 140[, [140; +inf[

For each interval, we have calculated the proportion of values included in, and we have drawn the values versus the 7 modal intervals, for HR_{mean} on one hand, and for HR_{max} on the other hand. The process has been done separately for Stress Conditions subjects, and No Stress Conditions subjects, represented on one graph as different bars (Fig. 5).
The results clearly show that Stress Conditions subjects present higher values than No Stress Conditions subjects, in both cases, HR_{mean} and HR_{max}.

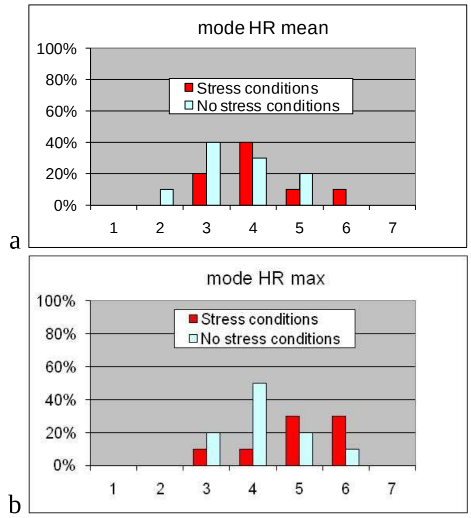

Fig. 5a & b. Modal analysis of HR for mean and max values during the Stress-test

We thus validate the previous results cited above ("Background" section), claiming that for short term occupational stress, heart rate increases. And, according to the analysis presented above and showing the importance of the mean and maximun heart rate, we accept HR_{mean} and HR_{max} as relevant physiological parameters for state of stress characterization.

From a qualitative standpoint, we can notice that these heart rate values are depending on the physiological state of the subject. We can then decide that the physiological dependence of HR_{mean} can be expressed by considering the increase from a basic value which is usually the heart rate at rest for a subject lying down, $HR_{mean\ rest\ lain}$; this parameter is used to being measured when the subjects has been lain for ten minutes.

Considering the same kind of dependence for HR_{max}, we must notice that this value is reached because the heart rate increases under Stress Conditions, and as more as HR_{mean} is high, as more the probability of HR_{max} to be high is important (Fig. 6). We then suggest to consider a relative value of this increase in terms of the difference between HR_{mean} and HR_{max}, noted $HR_{max\ ampl}$.

The modal analysis for the values of

$$(HR_{mean} - HR_{mean\ rest\ lain})$$

on one hand, and of

$$HR_{max\ ampl}$$

on the other hand, is done according to modes defined as follows, expressed in bpm :

[-inf; 5[, [5; 10[, [10; 15[, [15; 20[, [20; 25[, [25; 30[, [30; +inf[

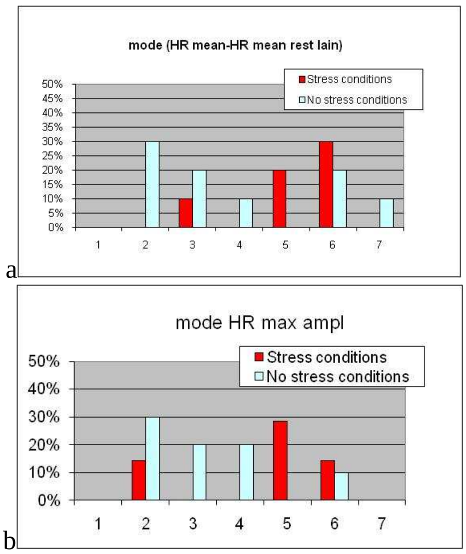

Fig. 7a & b. Modal analysis of delta HR values obtained during the Stress-test

The results clearly show that Stress Conditions subjects present higher values than No Stress Conditions subjects, in both cases. Yet, the discrimination of both states of stress is less marked for $HR_{max\ ampl}$. Nevertheless, we shall prefer these parameters than the previous ones because they take into account the physiological characteristics of the subjects.

We thus accept ($HR_{mean} - HR_{mean\ rest\ lain}$) and $HR_{max\ ampl}$ as relevant physiological parameters for state of stress characterization.

For further analysis, we need to build a stress coefficient that will take into account this double relationship. We can formulate it as follows:

- The stress coefficient is

  $$f(HR_{mean}, HR_{max}, HR_{mean\ rest}),$$

  where $HR_{mean\ rest}$ designates a reference HR at rest which can be lying down or sat,
- The stress coefficient varies as HR_{mean}, as HR_{max}, as ($HR_{mean} - HR_{mean\ rest}$), and as $HR_{max\ ampl}$
- Physiological consideration suggest to consider relatives values rather than absolute values for heart rate parameters, which engage us to build the stress coefficient as a function of ($HR_{mean} - HR_{mean\ rest}$) and $HR_{max\ ampl}$ rather than a function of HR_{mean} and HR_{max}.

We thus formulate the stress coefficient as follows:

$$f(HR_{mean} - HR_{mean\ rest}, HR_{max\ ampl})$$

From a strictly mathematical standpoint, we can make the assumption that K_s varies as the result of the increase of HR_{mean} from $HR_{mean\ rest}$, and $HR_{max\ ampl}$. It leads to introduce a stress coefficient K_s written as:

$$K_s = (HR_{mean} - HR_{mean\ rest}) \cdot HR_{max\ ampl}$$

In order to know if K_s can reflect the state of stress, we have done as above a modal analysis according to modes defined as follows, expressed in bpm^2 :

[-inf; 50[, [100; 200[, [200; 300[, [300; 400[, [400; 500[, [500; 600[, [600; +inf[

For each interval, we have calculated the proportion of values included in, and we have drawn the values versus the 7 modal intervals, for K_s in No Stress Conditions on one hand, and for K_s in Stress Conditions on the other hand, represented on one graph as different bars.

The results show clearly that Stress Conditions subjects present higher values than No Stress Conditions subjects, in both cases, as obtained for previous heart parameters (Fig. 7).

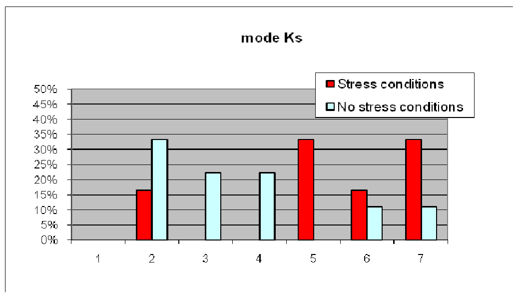

Fig. 7. Modal analysis of the coefficient of stress during the Stress-test

We thus validate the stress coefficient defined as:

$$K_s = (HR_{mean} - HR_{mean\ rest}).HR_{max\ ampl}$$

We shall see further that this coefficient can be simplified from a mathematical standpoint and some pragmatic considerations.

As explained above, a score is calculated to evaluate each subject's success taking the test: one point is attributed for each right answer. Nine answers are considered, and a mean value is calculated to give the performance coefficient for each subject.

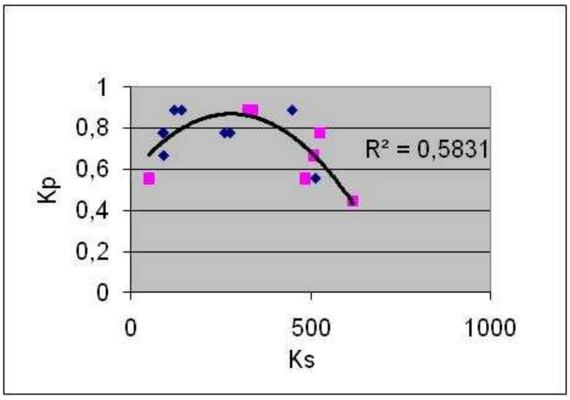

Fig. 8. Performance coefficient K_p plotted vs stress coefficient K_s discriminates the No Stress Conditions (dark diamonds) and the Stress Conditions (clear scare) for the Stress-test' subjects

The performance coefficient plotted versus the stress coefficient K_s gives an inverted U curve (Fig. 8), which is not without reminding the Yerkes curve type (Yerkes & Dodson, 1908).
The coefficient of determination is rather good: R^2=0.58 p<0.01)
To evaluate the robustness of the correlation, a F-test has been done with the null hypothesis that the model fits the experimental data. Calculation gives $F(1,28)=0.85$ for a critical value $Fcrit(1,28)=7.62$, $p=0.01$. The null hypothesis cannot be rejected and the correlation is kept as acceptable.

Furthermore, the graph discriminates the No Stress Conditions (dark diamonds) and the Stress Conditions (clear scares). If we consider the set of dots as a global image of the state of stress of people, and if we consider the median value as the threshold between two parts of the sample, one stressed and one not stressed (as done by others; see for example the DARES report, 2008), we shall find that this threshold corresponds to the flattering off of the bell graph, with more than 81% of the subjects on the right side of the plateau according to the test they respectively took.

These elements lead to several conclusions:

- The tasks built for the test are actually of two kinds: No Stress Conditions and Stress Conditions, as the subjects finally show two states of stress clearly separated materialized by the flattering-off threshold. This leads to the conclusion that the 3-level qualitative scale used to create the conditions of test is effective and confident.
- The curve drawing the performance coefficient versus the stress coefficient *Ks* gives a satisfactory description of the stressed state of subjects, and of their linked performance, and it matches the Yerkes model: more the subject is stressed, more s/he will be efficient, until a threshold of stress over which the subject will enter a cognitive disorder zone that will reduce her/his performance.

We must yet consider the pragmatic side of the method. We claimed that our purpose is to develop a simple protocol, requiring basic metrology and simple straight data analysis, to be used on training simulators by the instructors, who are not necessarily experts in medical researches. One problem then appears: the measurement of the heart rate at rest when the subject is lying down. In situations of training sessions on simulators, observations show that this operation is not easy. We have seen several cases for quite different professions, and every time, this parameter is not measurable within the time of the sessions:

- For all cases, training sessions are overloaded and do not allow to spend ten minutes to measure the heart rate at rest.
- In most cases, no place devoted to such rest exists. Even if a rest room is made available for this purpose despite the problems of space in industrial or training centers, it will be for one person, and one session involves four to six persons for the nuclear reactor pilots, eight for the anesthetists, at least two for pilots of civil planes or harbor pilots: this means 20 to 60 minutes to be spent just for this measurement.

There is one solution that consists to try to find another heart rate parameter at rest: for example, we could choose the one measured during our test, just before taking the test (as described in the section presenting the protocol). But it has been observed that some of the subjects were stressed before taking the test, during the introduction speech (Fig. 9). It was assumed that this could be linked with the young age of the subjects, but the graph below, comparing both heart rate at rest lying down or sitting (in bpm) versus the subject age (in years) shows that it is not the case, but depends on the subject themself. Thus, the heart rate at rest for the subject sat just before the test cannot be kept as a valid reference heart rate.

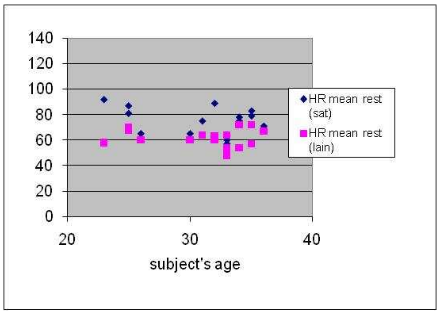

Fig. 9. HR at rest for the Stress-test' subjects

There is another solution that consists to ask the work physician to make such measurement during the annual check-up, but he will opposed that, as others, his time is too short to do all he has to do.

Another solution consists to ask all trainees to perform this measurement by themselves at home, for example in the morning, before getting out of bed. But you can be sure that the reliability of the data will be doubtful or for some of them, you will not have any value. To illustrate this point, we shall just take a few lines to explain what happened with the present test. At the end of the test meeting, subjects have been asked by the researcher to perform by themselves their own heart rate at rest. For this purpose, they have been asked to measure their heart rate during one minute, in the morning while waking up after sleeping at night, before leaving the bed. For more than the half subjects, the value was given into the week following the test. For a quarter of them, it occurred in several weeks, and for the last quarter, it took more than six months and was obtained after lots of recalls by email, phone and sms! All this induced a delay on our research.

For these reasons, we think that it is of great interest to introduce the reduced stress coefficient K_{sr} that does not integrate the heart rate at rest, and to check its solidity (Fauquet-Alekhine *et al*., 2011).

The reduced stress coefficient K_{sr} is defined as follows:

$$K_{sr} = HR_{mean} \cdot HR_{max\ ampl}$$

The performance coefficient plotted versus the reduced stress coefficient K_{sr} also gives a Yerkes curve type (Fig. 10). As for the K_r curve, the graph discriminates the No Stress Conditions (dark diamonds) and the Stress Conditions (clear scare). We must notice that the correlation is of the same order but slightly better (with a better coefficient of determination is R^2=0.69), and, more important, that the subject dots are characterized relatively to the others at same level (or not significantly far): in fact, introducing the heart rate at rest does not bring a valuable gain in terms of characterization of the subject's performance-stress inside the group.

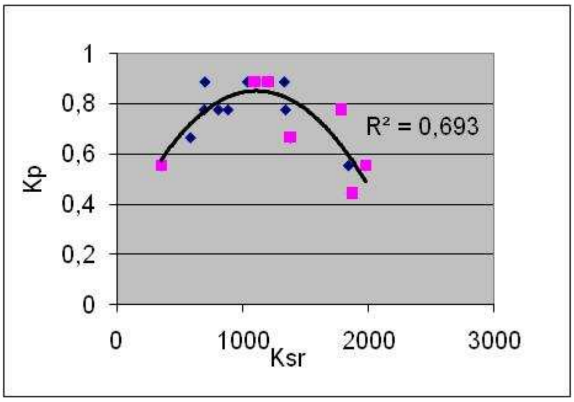

Fig. 10. Performance coefficient K_p plotted vs reduced stress coefficient K_{sr} discriminates the No Stress Conditions (dark diamonds) and the Stress Conditions (clear scare) for the Stress-test' subjects

Conclusions are:

- We demonstrated that a representative stress coefficient can be elaborated from the measurement of mean and max amplitude of the subject. These parameters are easily measurable by a classic heart rate meter provided in ordinary sport shops.
- This coefficient gives a good representation of the subject's state of stress during a work activity in which mental stress is involved, which means without physical stress.
- The subject's heart rate at rest can be used to calculate the stress coefficient, but does not give more information concerning the subject's state of stress according to the sample of subjects (narrow age interval). Thus, as it takes time to obtain this parameter, and as, in some application configurations, it can be difficult to ask people to lie down in order to have a rest before measuring the heart rate, the conclusions allow to use the stress coefficient without the heart rate at rest.

3.2.Application of the 3-LQS to French nuclear pilot training

Application of the 3-LQS for the French nuclear pilots training in order to evaluate the appropriateness of learning conditions have led to the assumption that some difficulties could occur at the end of the training cycle: Fig. 6 a & b permits a comparison between variation of stress at different stages of the training period using the 3-LQS rating, and results obtained by the French nuclear reactor pilots taking exams for the three last stages; it shows a similar variation, decreasing with time.

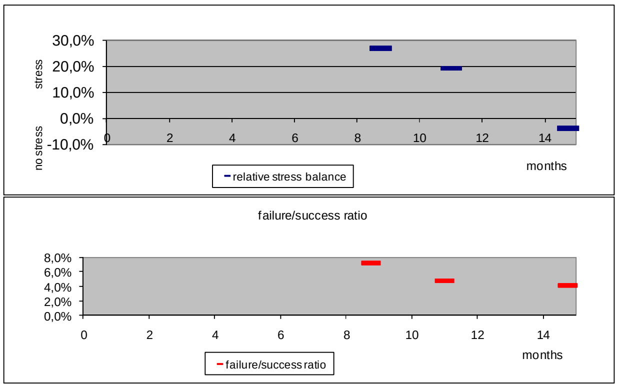

Fig. 6a & b. Comparison between variation of stress (upper graph) and results for the French nuclear reactor pilots (bottom graph) during the training cycle (X-axis expressed in months); they show a similar variation, decreasing with time.

The correlation coefficient (Fig. 7) related to the evaluated stress balance by the 3-LQS and the failure/success ratio at the pilots' exam along the training period is r=0.83, p<0.05.

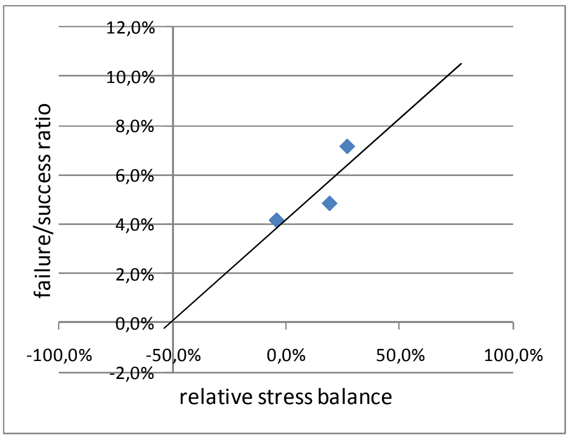

Fig. 7. Correlation coefficient related to the evaluated stress balance by the 3-LQS and the failure/success ratio at the French nuclear reactor pilot's exam along the training period.

Figure 7 suggests that the full success (0% for the failure/success ratio) might be reached at -50% on the relative stress balance axis (intersection of the fitted curve with the X-axis). Further studies based on the 3-LQS indicate that, in order to reach -50% of relative stress balance for the training, the variables to be worked are the self-confidence, the task definition, and mainly the documentation arrangement.

Individual interviews of a several pilots have then been conducted. They have been asked what was the more difficult step in the initial training cycle, and why. They all agreed that the more difficult was the COSP (disturbed situations) occurring between the eighteenth and tenth month. They explained that is was simulations of difficult situations because disturbed, and not frequently encountered in non-simulated situations. These rare situations imply to use procedures which are not often applied. So they are not well known by the pilots, and less ergonomic. This last specificity seems to be due to the fact that they are less used, so less adjusted to the user by the writer since the user makes less remarks concerning those documents compared to others daily used. The result is that COSP offers to the pilots disturbed situations to be dealt with complex and non-ergonomic procedures, with little feedback from the experienced colleagues in the daily work since these are rare situations.

One could say that it is now time to proceed to some experiments with heart rate meter during the nuclear reactor pilots' training. Obviously, this would be of great interest to reach more accurate conclusions than the above.
Unfortunately, this is not possible, especially for reasons of policy: the past five years have been a period of hard negotiation between the union trades and the company direction concerning the periodical evaluation guidelines of reactor pilots. This case is too fresh in mind for science to come and study what is going on during pilots' tests: results could be used for policy objectives and interpreted by others in a way we would not agree with, without the possibility of making changes. To proceed to such studies, ethic conditions must be clearly defined at first with all those implicated.

3.3.Application of the 3-LQS and performance vs stress analysis to anesthetist's training

Application of the 3-LQS for anesthetist residents' training has detected stressful conditions (Fig. 8).

Application of the developed protocol studying performance vs stress (qualified with the Stress-test) has confirmed stressful conditions, showing that most of the subjects were in a cognitive disorder zone on a K_p vs K_{sr} graph of Yerkes type curve (see Fig. 9), on the right side of the bell graph.

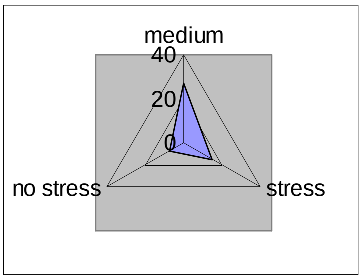

Fig. 8. The 3-level qualitative scale radar graphs applied to the anesthetist residents' training.

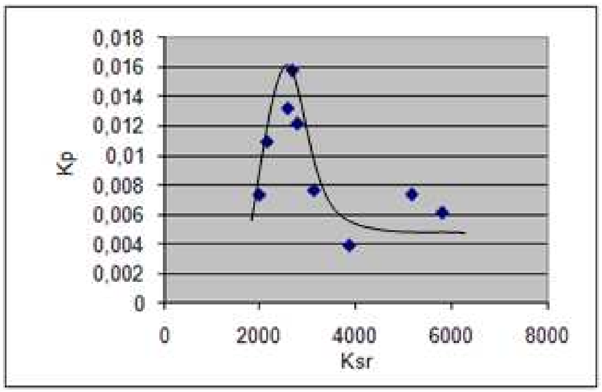

Fig. 9. Performance coefficient K_p plotted vs the reduced stress coefficient K_{sr} in case of anesthetists' full scale simulator training.

Analysis of the factors leading to stressful conditions done with the help of the 3-LQS shows that residents need to be more familiar with the simulator and with the activity before being involved in this kind of working situations.

3.4.Comparative analysis

Comparison between both trainings, and analysis done for each, have led to suggest improvements for each profession.

It has been noticed that weaknesses for one may be a factor of no importance for the other. For example, confidence in documents in real time for nuclear reactor pilots appears a necessity for them and the lack of confidence is thus a weakness. On the contrary, anesthetists do not care as they use their memory: having procedures in surgery theatre and reading them during the operation is not compatible with the work. Thus, the induced stress due to documents for pilots is not effective for anesthetists.

It has been noticed that some stress variables are not dealt with in the same manner. For example, pilots are progressively trained on simulator which makes them progressively familiar with the simulator while the anesthetists discover the simulator when trained.

For anesthetists' training, the main point of improvement would be thus to make them familiarized with the simulator before the training session itself, with a progressive approach of the simulator in several steps distributed on several days, including the familiarization with observers whilst working on simulator.

For the reactor pilots, the main point concerns the means available in terms of documents: procedures must be reviewed and ergonomic design must be obtained for the disturbed situation training.

For both professions, trainees must be able to perceive their knowledge and skills sufficient for the task in the perspective of increasing self-confidence: this implies to create or manage differently the previous steps of their training.

4. Conclusions

Demonstration is made for i) an effective 3-level qualitative scale able to rate stress conditions with regards of qualitative variables, ii) a simple protocol and device able to evaluate short term occupational stress. Tests are successful and suggest a reduced stress coefficient K_{sr} as a relevant and accurate parameter for this kind of stress rating. The Yerkes and Dodson theory (1908) is matched. Application is done successfully with anesthetists' trainees and comparison with reactor pilots' training is done. For both professions, suggestions are made concerning the training improvement. Further applications are planned for both professions in the coming years.

Symbols & Units

Symbol	*Quantity*	*Units (SI)*
HR_{mean}	Mean heart rate	bpm
HR_{max}	Maximum heart rate	bpm
K_p	Performance coefficient	none
K_{sr}	Reduced stress coefficient	none
p	Probability	none
r	Correlation coefficient	none
R^2	Determination coefficient	none

Appendix

The PDI questionnaire in its French version used immediately after taking the test. The 5 levels Likert type scale are used: *pas du tout, un peu vrai, plutôt vrai, très vrai, extrêmement vrai.*

01- Je me sentais totalement incapable de faire quoi que ce soit

02- Je ressentais de la tristesse et du chagrin

03- Je me sentais frustré(e) et en colère car je ne pouvais rien faire de plus

04- J'avais peur pour ma propre sécurité

05- Je me sentais coupable

06- J'avais honte de mes réactions émotionnelles

07- J'étais inquiet pour la sécurité des autres

08- J'avais l'impression que j'allais perdre le contrôle de mes émotions

09- J'avais envie d'uriner et d'aller à la selle

10- J'étais horrifié(e) par ce que j'avais vu

11- J'avais des réactions physiques comme des sueurs, des tremblements et des palpitations

12- J'étais sur le point de m'évanouir

13- Je pensais que j'allais mourir

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Causes and consequences: two dimensional spaces to fully describe short term occupational stress

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Abstract

The stress which we are interested in this study is a short term occupational stress, while people at work are asked to perform a task bounded in a short time interval (about several seconds to several hours). To characterize the stress, (macro)variables can be distributed among three to six dimensions (McLean, 1974; Palmer et al., 2003). Consequences due to stress are absent of the models. Our work aims to make the demonstration that the consequences (among which behavior) induced by the short term occupational stress are important to fully describe stress. – METHODS: In order to show the importance of behavior to characterize short term occupational stress, we have proceeded in two steps: the first one investigated whether stressful (resp. stressless) conditions gave mainly stressed (resp. non stressed) behavior analyzing performance versus stress, and the second one analyzed how apparent similar stressed subjects might give different consequences in terms of behavior. – RESULTS AND DISCUSSION: Stress in test conditions: Resulting data fulfill the theoretical proposal of Yerkes and Dodson (1908), divided into three main parts: i) the central part reflects the transient state for the subject in terms of stress effects, ii) the left part is linked to the positive state of stress or stable cognitive state, and iii) the right part concerns the negative state of stress or the potential cognitive disorder state. They remind the concept of Human Functional States (HFS) defined by Leonova (2009). The results illustrate the impact on the subject's behavior. Stress in working situations: Observations and interviews with trainers and trainees trained on full scale simulators for risky professions have been done, highlighting how apparent similar state of stresss can lead to different behaviors. It shows that both the source factors of stress and consequences induced by the situation of stress can be useful for its characterization. The two 3-D space model of stress: The conclusion is that stress is fully defined by a two 3-D space concerning source and consequences. The source 3-D is: i) the context dimension, ii) the request or job demand dimension (excluding the context), iii) the subject's characteristics. The consequences 3-D is: i) the psychological symptoms, ii) the physiological symptoms, iii) the behavioral symptoms, or resulting actions. In each 3-D space, the stress is defined by variables on each axis which determines a volume of stress. The first volume finds its consistency through the dimensions interactions and produces the consistency of the consequences volume in which dimensions interact together as psychological symptoms usually produce physiological responses, both making possible or not behaviors. The two spaces interact together, as symptoms produce a feedback on the source.

1. Introduction

This study deals with mental stress. For this reason, tests have been done without any physical effort (subjects are sat), and for application of the developed method, all cases involving strong physical efforts are taken out of the experimental data.

The stress which we are interested in is a short term stress, compared to long term stress linked with chronic stress exposure (refer for example to the studies of Schubert *et al.* (2009) who compare both kind of stress).

In general, stress occurs depending on endo- and exo-parameters for one subject. Endo-parameters can be the physical and psychological state of the subject, and exo-parameters can be the context. The stress will take different forms according to the parameters which will be of significant influence. We can suggest a list of short and long term kinds of stress:

- Stress due to physical demand: intensive short or long term stress mainly due to physiological response of the body (sports, hung up by the feet during yoga).
- Stress due to physical attack: both intensive short and long term stress (war battle field, street aggression).
- Stress due to physical contact with subject's agreement: intensive short term stress (patient in surgical intervention).
- Stress due to psychological exposure, short and sharp: mental intensive short term stress (verbal aggression).
- Stress due to psychological exposure, short and without violence: mental short term stress (taking

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an exam, dealing with a difficult task, physician during surgical interventions).

- Stress due to psychological exposure, long and without violence: mental long term stress (dealing with a difficult task at work for several days, physician during long surgical interventions, chronicle exposure to organizational stress at work).

In this study, we are concerned by mental short term occupational stress, and by its relationship to performance. The precision "short term" is important for the reasons briefly exposed above. In case of long term occupational stress, physiological parameters vary differently. Details are given below.

Different kinds of parameters exist that can contribute to occupational stress. But it would be a mistake to focus just on parameters generating stress for at least two reasons: the first one is that a subject's state of stress is usually induced by a combination of stressful and stressless parameters, and the second state is the fact that one parameter as the noise for example can be stressless (relaxing music) but can become stressful (industrial environment with noisy engines). Furthermore, their combined effects can be different than their individual effects (Liebl et al., 2012). Besides, parameters may depend on the subject or not. We may consider the parameters related to the subject themself which we shall call the endogenous parameters, and the one from outside, the exogenous parameters. The endogenous parameters concern the subject's psychology and physiology, while the exogenous parameters concern all those from the physical and psychological environment: temperature, surrounding noise, interaction with colleagues, time pressure, work load, decision latitude… All these parameters can be more or less stressful depending on their intensity. Some of them can even be stressless as illustrated above with the case of noise, which means that one parameter can evolve on a "one dimensional axis" with positive and negative values of stress. For this reason, instead of speaking of "parameter of stress", we shall prefer to say "variable of stress", according to the following considerations.

Considering the occupational stress, a lot of studies may allow us to build a list of all the variables involved in the rise or decrease of stress. Yet, such an exhaustive list would be a fastidious work with a fuzzy gain: a given work situation is not necessarily concerned by all the variables that could be listed. Some studies have determined specific stress factors for given professions (for surgeons: Arora et al., 2010; for anesthetists: Yee et al., 2005). We thus would conclude that for a given situation, a lot of them are not significant while others are relevant.
We can argue by few examples how a variable can be relevant in a context and not significant in another. For instance: Lazarus (1985) used the Hassles factors and Hopkins symptom checklist among which is "financial responsibility" and "future security". These two variables are macrolabelled and we should rather designate them as "macro-variables": the financial responsibility can be declined, for example, depending on the work activity and on the company where the subject works, as "the responsibility concerning the loss of money for the company due to the accidental destruction of materials", or "the stable financial balance of the team due to a safe management"; and future security may concerns "the stability of the subject's employment" or "the short term security of people at work due to a technical problem". These two macro-variables are giving here four variables. The difference between macro-variable and variable is the refined level of the description of the parameter. These (macro)variables can be concerned related to one or several dimensions of stress.

Many analysis have been done and several models exist to describe stress, performance, and their relationship. Among them for example, Karasek and his team (Schwartz, Pieper, & Karasek 1988) found the between-occupation variance was:

- 4.2 % for psychological demand
- 25.9 % for physical demands
- 34.7 % for control

and so suggested an interesting concept for stress at work (Karasek *et al.*, 1990 & 1998).
An interesting review has also been suggested by Staal (2004).

According to the second theory proposed by Karasek & Theorell (1990), these (macro)variables can be distributed among three dimensions describing the stress: the request or job demand dimension including the context, the subject's autonomy or decision control, and subject's social support perception.
Other models distribute these variables among three different dimensions: the subject's vulnerability, the context, and the stress factors (see Mclean, 1976), or over six dimensions: demand, control, support, relationship, role, change (see Palmer, Cooper & Thomas, 2003). As we shall consider stress at work, the stress is of occupational kind. We shall thus study short term occupational stress, at which people at work are submitted when they are asked to perform a task bounded in a short time interval (about several seconds to several hours). We shall study the relationship between performance and stress, and mainly the influence of the conditions of stress on the performance. Yerkes & Dodson (1908) gave a theoretical description of this relationship, assuming that performance rises with the stress level until a given threshold beyond which stress puts the subject in a cognitive disorder zone making to performance decreasing (Fig. 1).
Yet, in mathematics, the dimension of a space or object is informally defined as the minimum number of coordinates needed to specify each point within it. In a 3-D space, a point is fully defined by a set of 3 coordinates, and every objet is fully defined by a set of coordinates or a set of equations referring to the 3 dimensions. This is possible only if the dimensions are independent from one to another.

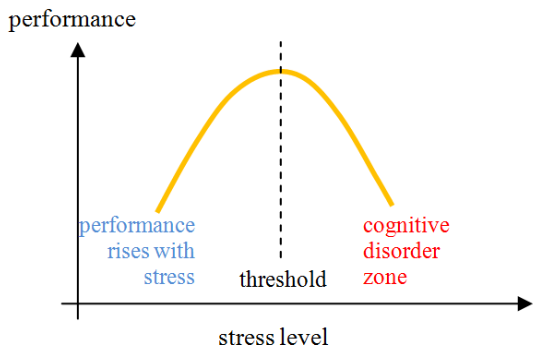

Fig. 1. The Yerkes & Dodson (1908) theoretical description of this relationship performance vs stress: performance rises with the stress level until a given threshold (extreme of the inverted U curve) beyond which stress puts the subject in a cognitive disorder zone making performance decreasing.

The following analysis will show that the quoted models do not match these characteristics ,and that for the considered kind of stress, some dimensions are missing. Specifically, we aim to make the demonstration that the consequences induced by the short term occupational stress are important to fully describe stress. Among them, the behavior as a resulting action is an important variable to be taken into account.

2. Methods

In order to show the importance of behavior to characterize short term occupational stress, we have proceeded in two steps: the first one investigated whether stressful (resp. stressless) conditions gave mainly stressed (resp. non stressed) behavior analyzing performance versus stress, and the second step analyzed how apparent similar stressed subjects might give different consequences in terms of behavior.

2.1 Method - step 1: performance versus stress

According to the knowledge of stressing parameters at work, we built a test (thereafter named "Stress-test") and its context (Stress and No Stress conditions).

The test was made up of 12 questions. A performance coefficient K_p, based on the right answers given by the subject, has been calculated for each subject. The whole test protocol was the same for both Stress and No Stress Conditions. The difference came at the time of taking the test.

Our subjects (*N*=18; 50% male) were healthy, middle aged (25-35 yo), charter engineers or physicists, French, living in France. Choosing people with the same academic background and the same kind of job is very important, because they are all able to understand and deal with the questions of the test by the same way. It means that the academic background, the professional job, and the social level, are fixed parameters. Heart rate has been measured using a Polar FS2c for physiological measurement of stress.

The whole test protocol was the same for both Stress and No Stress Conditions. The difference came at the time of taking the test.

The subjects were met in their job office. The appointment was always planed between 9:00am and 12:00am in order to avoid post-prandial effect due to breakfast or lunch. They were asked not to smoke or drink any exciting beverage (coffee, tea, cola…) at least one hour before taking the test. Every time, the door was closed and the researcher was alone with the subject, not disturbed. The phone did not ring.

The protocol of the test was as following.
As an introduction, the researcher reminds the subject of the aim of the meeting, and asks him/her to pick a paper randomly among several. This is done so that the researcher does not choose the case which will be studied: the drawing decides whether the subject will work in stress conditions or not. To maintain the balance, the drawing is done every two tests: after one case, the opposite case is always studied.

Then, the researcher explains the need for measurements of the heart rate using a Polar heart rate monitor and the metrology is then applied to the subject. The researcher explains the way it would go on: taking the test, checking together the results, and then the researcher explains why the test is done as it is.

The protocol to obtain the two conditions for taking the test is fully described elsewhere (Fauquet-Alekhine et al., 2012). They are elaborated according to a work analysis of the test conditions done a priori and using the 3-level qualitative scale (see Fauquet-Alekhine et al., 2011 and 2012): i) the Stress Condition has been built to be stressful for the subject, and ii) the stress factors of the so called No Stress Condition has been suppressed or lessened. We called it "No Stress" to simplify writing but in fact, stress does exist during this test as every job demand creates a stress at a more or less important level.

As we can see, for the Stress Condition test compared to the No Stress Condition test, the work context is elaborated for the subject to perceive as many factors as possible as a constrain.
The data obtained have led to match a Yerkes & Dodson curve type.

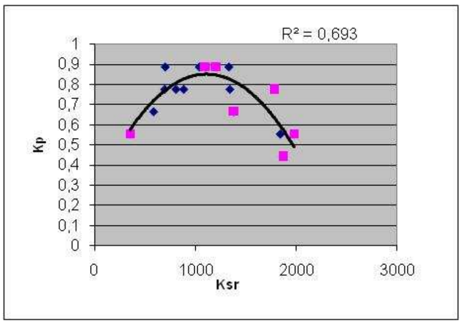

Fig. 2. Experimental data obtained during the Stress-test, plotted with performance coefficient K_p vs reduced stress coefficient K_{sr} and fitting a Yerkes & Dodson (1908) curves for a short mental occupational stress (Fauquet-Alekhine et al., 2011). The determination coefficient of polynomial fitted curve is $R^2 = 0.69$.

The study is based on a previous work (Fauquet-Alekhine et al., 2011 and 2012) in which it was demonstrated that a Yerkes & Dodson curves could be fitted for a short mental occupational stress (Fig. 2): plotting the subjects' performance measured through the performance coefficient K_p vs the state of stress rated by the reduced stress coefficient K_{sr} gives a bell curve where subjects working in stressful conditions are well discriminated on the right side of the graph (clear squares) from other subjects.

These results are now used to conceptualize what have been named above abusively No Stress and State of stresss according to the theoretical suggestion of Yerkes & Dodson confirmed by our finding.

2.2. Method - step 2: apparent similar stress for different type of stress.

The second step has been induced by a basic remark shared by several trainers working on full scale simulators, saying that trainees were trained to deal with stress as they were stressed during simulation training sessions. The question then was to know whether the stress induced on simulator was the same than during work in non-simulated situations.

This has led us to perform observations and interviews with trainers and trainees trained on full scale simulators for risky professions. Observations have been done both in simulated and non-simulated situations. The professions concerned by observations and interviews were aircraft pilots, harbor pilots, and nuclear reactor pilots, all working in French companies.

3. Results & Discussions

3.1. Stress in test conditions

Resulting data obtained with the Stress-test fulfill the theoretical proposal of Yerkes and Dodson (1908), suggesting that a stressed subject will have a better performance than if not stressed until a given threshold. Measurements have been conducted in a context of training on simulator, and results have shown the same differentiation: a stress threshold separating non stressed subjects from others. Application of these conclusions has been done for event analysis in industry to illustrate how the potential cognitive disorder state induced by stress could produce an inadequate behavior (Fauquet-Alekhine *et al.*, 2011).
Thus, in case of mental short term occupational stress, the stress has a positive effect on the performance until this threshold, and beyond it, subjects are less performing because the effect of stress becomes negative: subjects may be concerned by cognitive disorder that makes them unable to perform correctly the task.

Our findings thus suggest that the Yerkes and Dodson curve can be divided into three main parts:

- the central part reflects the transient state for the subject in terms of stress effects,
- the left part is linked to the positive state of stress or stable cognitive state,
- the right part concerns the negative state of stress or the potential cognitive disorder state.

These different states remind the concept of Human Functional States (HFS) defined by Leonova (2009). They are drawn on the graph presented in Fig. 3.

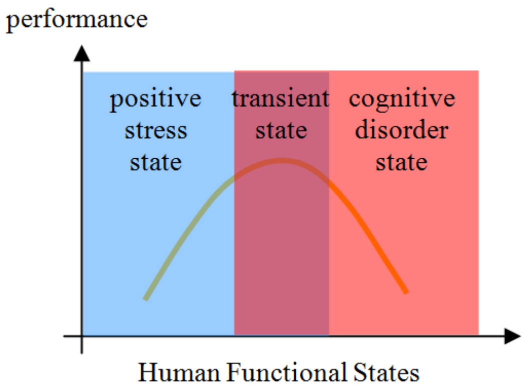

Fig. 3. Human Functional States (HFS) divided into three main parts: i) central part: transient state for the subject in terms of stress effects, ii) left part: positive state of stress, iii) right part: potential cognitive disorder state.

With regards to these proposals, what have been named abusively in previous sections No Stress and State of stresss can be now refined as three main levels of HFS defined as follows:

- Low potential of stress (LPS)
- Efficient potential of stress (EPS)
- High potential of stress (HPS)

Application of these results has been done for event analysis in industry as follows. On an industrial plant (more than 1000 employees), the work analyst has been called upon in order to find the causes of the action of a field worker who had opened a valve while it was forbidden and had provoked an important loss of production with potential safety consequences. It happened in 2009, while the company had made great efforts during the past years to make the interventions more reliable, and the management did not understand how such an act could have happened. When the work analyst has met the field worker, he has asked him to explain the whole story in details. The work analyst was astonished by one detail: during the first half part of the story, the field worker appeared to work as a good professional, but during the second part, he appeared to work as a man who did not know the job at all. During the interview, the analyst has noticed several details which showed that in work situation during the second part of the story, the field worker was frightened. Step by step, the analyst has put into light that the worker was able to work as a good professional until the time he had entered a room containing valves and ducts with high vapor pressure. Then he discovered that the worker had known, several years ago, some colleagues being injured by vapor loss in such a room, and that entering the high vapor pressure room was frightening him. Scared by the place probably induced by the remembrance of the colleagues' accident, the field worker could not work anymore correctly. The frame of this event matches HFS defined above as the potential cognitive disorder state.
Furthermore, this example illustrates how the potential cognitive disorder state induced by stress can produce a inadequate behavior.

These results illustrate that the way the subject is able to perform the task using know-how and skills depends on the HFS, and the HFS may determine the subject's behavior.

3.2. Stress in working situations

The previous results show that the behavior can appear as a consequence or a result of the stressed state of the subject. The following intends to demonstrate that similar apparent stressed states can yet be related to different behaviors. For this aim, observations and interviews with trainers and trainees trained on full scale simulators and on non simulated situations for risky professions have been done. Stressful situations have been observed and put into discussion during the interviews.

An aircraft instructor explained having lived a very specific situation, just once in his life. He was training a team for aircraft piloting on full scale simulator. This simulator was equipped of screens in place of the windows to reproduce the outside of the cockpit, and installed on hydraulic motion in order to reproduce the movement and vibrations of the plane during the flight. While the team had some difficulties to perform the task, the simulated flight derived to a simulated dramatic situation the end of which would be the crash. According to pedagogical goals, the instructor let the team try to deal with the problem, unfortunately without any success and the plane was falling down at high speed. On the screen, the ground was approaching more and more. In the cockpit, vibrations were increasing. The 2-pilot team was doing its best in vain and when the screens showed the ground up to the plane, the pilots put their arms on their face to protect themselves from the impact. But they were on simulator! The instructor was very surprised of such a behavior. According to him, in this specific case, the trainees had felt a stress similar to what could be felt in a non-simulated situation, and the pilots had acted exactly as if everything was a real potential crash and finally, with their arms on the face, as a real crash.

In this case, it is difficult to claim whether pilots' stressed states are similar or not between simulated and non-simulated situations. Anyway, they are rare. The following examples are more common.

Interviews with a Merchant Navy trainer pointed out that the observed stress could seem to be the same in non-simulated and simulated situations (Fauquet-Alekhine, 2011), but in fact not. This similarity only concerned the symptoms. When the resulting action was considered, what was done by the stressed trainee on simulator was not the same than what was done by the same stressed person in non-simulated situation. It depended on the source of stress: on simulator, the trainee was stressed because of the evaluation (source), and he was leading the ship close to the edge very slowly (consequences), while in the real harbor, the subject was stressed because of the workload and the number of vessels waiting to enter the harbor (source). He then led the ship close to the edge much faster (consequences). In this case, the state of stress seemed to be the same in simulated and non-simulated situations through the symptoms, but differed through the induced behavior.

Interviews with a safety expert working on a nuclear power plant and trained to pilot nuclear reactor in accidental situations gave the same result. The trainee explained that he had co-piloted a reactor in accidental situation twice during his career (4 years). He said that in these situations, he felt a stress and his main concern was the safety of the industrial plant and its environment (source). Everything he did in these working situations was induced by this concern: act fast and efficiently (consequences). But on the simulator, it was quite different: dealing with the reactor piloting in case of accidental situations, his main concern was to prepare the following debriefing with the trainers (source), during which he would have to show his good understanding of the situation. For this aim, the way he took more time to read the procedure, and the kind of information he had gathered (consequences) were quite different and more numerous than during a non-simulated situation. Nevertheless, during both situations, he felt the same state of stress. In this case, the state of stress felt by the subject seemed to be the same in simulated and non-simulated situations through the symptoms, but differed through the induced behavior.

This has highlighted how apparent similar HFS of stress can lead to different behaviors. As we have seen, the difference is due to the stress source. Thus, the source factors of stress are important to characterize the stress. But these examples also show that consequences induced by the situation of stress can be useful for this characterization. If we think to the graph shown on Fig. 3, each HFS can be related at least to two different subject's behaviors, linked both with the source and the aimed action envisaged by the subject.

We have obtained similar observations for aircraft pilots, nuclear pilots, and anesthetists. Here, we can suggest that the behavioral symptoms must be taken into account to define the stress. These findings lead us to suggest the Stress model presented in the next section.

3.3. The two 3-D space model of stress

According to us, an adequate model of the stress phenomenon must be based on independent dimensions as said above. When we check all our studied cases, we find some relationship between factors.

Our own observations show that:

- If context does not include all stress factors, many Stress factors are part of the context. Thus stress factors and context cannot be thought as two different dimensions since not independent.
- Effective subject's autonomy depends on the organizational context, which let us suggest that the appropriate dimension is context rather than autonomy.
- Subject's perception depends on subject's state, i.e. subject's characteristics. They are also called sometimes subject's vulnerability (Polevaya et al., 2010), but it is an inappropriate noun as it must be also considered the subject's strength.
- Social support and relationship are not independent.

The conclusion is that the appropriate dimensions are:

- the context dimension (social, organizational, environmental),
- the request or job demand dimension (excluding the context),
- the subject's characteristics.

Subject's characteristics refer to the psychological abilities of the subjects to be sensitive or not to stressful conditions (for exemple: Zvolensky et al., 2005), and these refer themselves to physiological characteristics as demonstrated by many researches. For example, Albert, Shchepina et al. (2008) showed that rats could be more or less tame according to adrenal glands size, levels of serum corticosterone, blood glucose levels, concentrations of amino acids, serotonin and taurine levels.

But our aforementioned observations show that these three dimensions are not sufficient to fully describe the stress phenomenon; as a matter of fact, we must admit that this 3-D model only describes the source of stress. In the interactional approach, the stress is a result of the interaction of the three dimensions which produce consequences that themselves describe the stress by what we call "symptoms" (Fauquet-Alekhine et al., 2011). Symptoms are consequences of specific stimuli; they are responses of the subject to these stimuli. We shall gather here subjective and physiological consequences as "symptoms" (including "signs", while the strict meaning of "symptom" would only concern the subjective consequences, the objective ones being designated by "signs"). Symptoms may be physiological, psychological. As an extension, we can also speak of behavioral symptoms.

Physiological symptoms can be measured as heart rate for example, and psychological symptoms can be observed through physiological symptoms or known through questionnaires of perception. According to these symptoms (Fauquet-Alekhine et al., 2012), one can define the type of stress and its intensity. Here, we can see that the symptoms must be taken into account to define the stress.

The conclusion is that stress is fully defined by two sets of dimensions concerning on one hand the sources and, on the other hand, the consequences.

As described above, the appropriate set of dimensions describing the sources is 3-D:

- the context dimension,
- the request or job demand dimension (excluding the context),
- the subject's characteristics.

And the appropriate set of dimensions describing the consequences is also 3-D:

- the psychological symptoms,
- the physiological symptoms,
- the behavioral symptoms, or resulting actions.

In each 3-D space (Fig. 4), the stress is defined by variables on each axis which determines a volume of stress. The first volume finds its consistency through the interactions between the three dimensions (context – demand – subject's characteristics), and produces the consistency of the symptoms volume in the second 3-D space (psychological – physiological – behavioral). These three dimensions interact together as psychological symptoms usually produce physiological responses, both making possible or not such behaviors. And the two spaces interact together, as symptoms produce a feedback on the source.

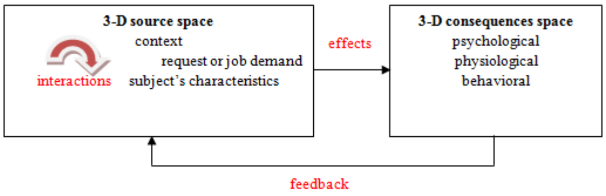

Fig. 4. The two 3-D spaces model for short term occupational stress

Unfortunately, this full description of stressed HFS, if can serve the characterization, may not always serve the predictive extrapolation: as stressed HFS is contextual, a given subject in a given stressful context α related to a HFS described by variables in the two 3D-spaces will not necessarily be the same in another given stressful context β. Similarly, if context α is more stressful than context β, the subject will not necessarily be more stressed in context α than β.

Proof is the following results which reinforce the suggestion that consequences are of great importance to fully describe the HFS as consequences vary from one subject to another in a given context.
Among the subjects participating at the Stress-test experiments described in sections 2.1 and 3.1, three of them were involved in a training program for having a new job in the same company. For this aim, they had to take exams both on simulators and in front of an examinatory board. We have compared the results obtained at the Stress-test and the results in front of the examination board, for each subject, named A, B and C. This has been done to evaluate the influence of the contextual effect on the stressed subject's behavior, and to weigh up the importance of the subject's behavior to characterize the HFS. Evaluation of the perceived stress has been done using the PDI questionnaire according to our previous work (Fauquet-Alekhine et al., 2011 and 2012). Results are shown on Fig. 5, for both contexts: Stress-test and examinatory board.

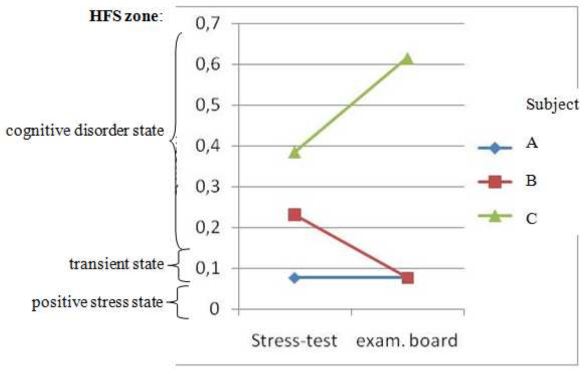

Fig. 5. Comparison of HFS for subjects A, B and C for two different contexts: taking the Stress-test and in front of the examinatory board. Evaluation of the perceived stress has been done using the PDI questionnaire according to Fauquet-Alekhine et al. (2011).

The results show three different cases for each subject:
- subject A remains in transient HFS for both contexts: Efficient potential of stress (EPS),
- subject B varies HFS from potential cognitive disorder HFS (HPS) to transient HFS (EPS) corresponding to the threshold zone defined by Yerkes and Dodson,
- C increases the level within the potential cognitive disorder HFS (HPS).

It appears here clearly:
- the contextual character of stressed HFS and the great influence of the variables linked with the subjects' characteristics identified inside the 3-D source space of the model proposed in section 3.3,
- the behavioral variation from one subject to another showing that consequences are important to the description of HFS.

4.Conclusion

On the basis of the study of performance vs stress, we have shown how the mental short term occupational stress had to be fully described in a two 3-D spaces model. We have questioned the apparent limits of this model in terms of predictive extrapolation from one known situation (including the subject) to another. Further investigations will be conducted to analyze the performance level vs stress related to the context and also to analyze whether the subjects' characteristics identified within the 3-D source space of the model may be characterized in order to refine the predictive nature of the model.

According to the results that we shall then obtain, the stress management will be think in term of dealing with the context variable (changing the context influence; see Fauquet-Alekhine et al., 2011) or dealing with the subject's characteristic within the context through self-regulation (Kuznetsova et al., 2005; Leonova et al. 2009 & 2010).

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Anticipating and reducing risks on nuclear industrial plants

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Abstract

Nuclear power plants must constantly revisit their organizations to ensure continuous improvement in their level of safety. As with any complex and risky socio-technical system, training simulation is an indisputable resource and unquestionably used. Experiment results presented here show the efficiency of a decontextualized software such as a Serious Game to improve industrial workers' performance expected to apply Human Performance tools. In such a context, using Serious Game as a pre-performing task helps to anticipate and reduce industrial risks by increasing the reliability of the task performance.

1. Introduction

Exploitation of nuclear power plants implies a high level of safety and of work activity reliability. The production division of EDF always tries to find organizational solutions in order to reinforce those lines (see for example: Le Bot, 2004; Fauquet, 2007, 2008; Fauquet-Alekhine, 2012a). Since 2006, a Human Performance Program has involved all the nuclear power plants of EDF, within one topic concerning reliable professional practices for workers in the field often called by the international community: Human Performance tools (HP tools).

Benchmarking done abroad and concerning different industries has shown HP tools could help to avoid events (see for example Fauquet, 2009; Fauquet-Alekhine, 2010; Fauquet-Alekhine & Pehuet, 2011). The production division of EDF has selected 6 of them to be applied during activities (Theurier, 2010; Fauquet-Alekhine, 2012b).

The HP tools can be described as follows (Theurier, 2010):

- The Pre-job Briefing: located after the preparation of activity (including risk analysis) and its appropriation by the interveners, and just before the activity itself, the Pre-job Briefing is a specific phase of mental preparation and coordination for the interveners: sharing of perception, implementation of key risks in working memory, ...
- The Take a Minute: located on the workplace and just before its start, it asked workers out of the urgency of action for analytical look at the work environment: am I on the right unit? the right track? the right equipment? Do I have a risk of accident? ... The "Take a Minute" is also used in case of interruptions or progressive drift of the situations outside the planned framework.
- Self-check: it permits to avoid the usual global analogical way of reading. It asks analytic reading (read aloud and point the finger) of the identifier on the procedure and its corresponding tag on the equipment before implementation of an action.
- Peer-check: it asks, in addition to the self-check, another person to verify the coherence between the intention announced by the internener and the draft of the action to complete before it starts. It helps strengthen vigilance.
- The Debriefing: it definitely finishes an activity by expressing difficulty and facility encountered in the action and the "innovative" means in place to achieve the result. It is a point of engagement inside a loop of progress for future interventions.
- Reassured communication or 3-way communication: it allows to ensure that information has reached the consciousness of the intervener while s/he was focused on his/her activity. The addressee must repeat the information received and the addresser must confirm the accuracy of the repetition.

These HP tools are expected to soon be part of the professional practices of any workers of the French

* This work has been presented at the IVth *E-Virtuoses Conference*, 23-24 May 2012 - Valenciennes – France

nuclear industry. They focus on the realization phase of interventions and make the link with preparation phase and feedback phase (Fig. 1).

For this aim, specific training programs have been implemented both for field workers and for managers. Even if the results are very good in terms of safety results (Fauquet-Alekhine, 2012b), work analysts and experts evaluate the progress as less good than what might be expected. Furthermore, observations in the field show that indeed HP tools could be applied by field workers more efficiently and that HP tools are not yet part of the professional practices as planned. Thus, new training solutions have to be found, and transference programs have to be built according to these new solutions.

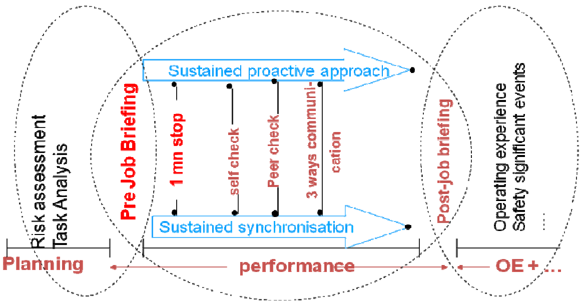

Fig. 1. The six Human Performance tools expected to be part of professional practices, presented according to the three work activity phases: planning, performance, operating experience.

As this paper is devoted to the training aspect and as the conference aims to deal with virtual training tools, we shall focus on one of the solutions sought by the nuclear power plant of Chinon related to these topics. The solutions sought are based on the following findings:

- From the pedagogical standpoint, it can be efficient to train people to new practices in a definitely decontextualized situation, provided that the following transference period of know-how is adapted for the trainees to develop the expected skills (Fauquet-Alekhine, 2011).
- In 2011, an experiment has been conducted on the nuclear power plant of Chinon suggesting to workers, during a half-day demonstration, the implementation of HP tools during decontextualized playful activities (Fig. 2 to 4). The result was that several hundreds of workers came here and took real pleasure to apply HP tools. The observations were quite different from those which could be done in the field: it appeared that both characteristics (decontextualized and playful) and their combination could be a successful blend for the HP tools to be more easily accepted and applied by workers.

Fig. 2 a & b. Implementation of HP tools during decontextualized playful activities. Here, a factice bomb must be switched off.

Fig. 3 a & b. Implementation of HP tools during decontextualized playful activities. Here, a) very special order for shopping, b) a labyrinth in which the way must be found according to clues given by a coworker beyond the wall.

Fig. 4. Implementation of HP tools during decontextualized playful activities. Here, a car race with radio remote control and a part of the circuit hidden behind a wall where a coworker gives clues for the car to keep on the race.

The solution then is oriented to a pedagogical tool presenting these two combined characteristics. The form is a serious game in its playful dimension called "ludus" by the experts (see the recent analysis of Alvarez & Djaouti, 2011).

2. Material and methods

The experiment has been conducted in April 2012. Subjects were invited for taking a test involving three devices. The test concerned one, two, or three of them according to a specific order. The three devices (Fig. 5 a to c) were:

1- A mock-up presents ducts and valves to be adjusted according to a procedure in order to obtain a sample of clear water knowing that valves and ducts are connected to a clear water tank or to a colored water tank. In case of mistake concerning the valves configuration, the sample is spoiled by ink. The subject is free to implement HP tools, but they are strongly recommended. This device has been identified as the reference activity (or the "real activity") since it is the physical context and the only one within which the sample of water can really be spoiled. The mock-up has been designed so that mistakes can easily occur : the two lines of valves and ducts are tagged with very closed labels. For example, "1SIV104VR" may be confused with "1SIB104VR", "1SIV105VR" may be confused with "1SIV105VA". Furthermore, the circuits are not aligned.

2- A virtual software specifically developed for the purpose: the previous mock-up is reproduced on the computer screen. The same activity is asked but everything is virtual. As in device #1, the subject is free to implement HP tools, but they are strongly recommended. This device is presented to the subjects as a virtual training simulator in order to obtain better results on device #1. According to previous work (Fauquet-Alekhine, 2011), the avatar is chosen female and peer as a co-worker rather than a teacher, in order to get better results from the trainee. The design takes into account research results linked with virtual training software. Recently, Beale & Creed (2009) noticed that these results depended on the role played by the agent: they suggested that an agent taking the place of a co-learner for the subject appeared to be perceived more positively than a tutor-agent. Burleson & Picard (2007), quoted by Beale & Creed (2009), found out that subject's gender had significant influence: female had better perception of the agent providing affect support than the one providing task support, while it was the opposite for male.

3- A serious game, no link with the activity of the devices #1 and #2, is suggested for the subject to have HP tools training. This Serious Game is an education game which aims to help people using the ATM device. It is available for free in English version on the Grey Olltwit Educational Software web site: www.greyolltwit.com. We have used it with French subjects in order to remind application of the HP tools. The subjects knew how to use ATM, but were not used to using it in English. The HP tools had to help to be efficient. The scenario was as follows: the subject had to imagine being in holiday in England and asked by an old woman for help using the ATM according to a check-list she gave him/her. The tasks to do were : change your PIN code, view balance account on the screen, withdraw 50 with a receipt, withdraw 50 without a receipt, print a mini statement.

The devices were used for tests involving each case according to the following order:

- Configuration A = 1
- Configuration B = 2 then 1
- Configuration C = 3 then 1

a

b

c


Fig. 5. a) Mock-up with ducts and valves to be adjusted according to a procedure. b) Software presenting the virtual device with ducts and valves to be adjusted according to a procedure. c) Serious Game for HP tools training.

Subjects are workers (*N*=23, 80% male in agreement with the industrial context) and have taken the test according to the distribution among the three possible configurations given in table I. These workers are expected to be familiar with the reference situation task (device #1) and with the HP tools. They are mostly technicians or engineers.

Table I. Subjects distribution among the possible configurations.

Configuration	*Subjects distribution (%)*
A = 1	26
B = 2-1	52
C = 3-1	22

Analysis has been done in order to appreciate how device #2 (virtual) or device #3 (Serious Game) could influence the results obtained on device #1.

3. Results & Discussion

Performance has been evaluated only on the device #1 as it has been identified as the reference activity, devices #2 and #3 being training devices. Performance rating has been done according to the expected final result (clear sample of water) and the number of mistakes done during the activity. A mistake is identified as soon as the subject does not touch at once the right valve or does not turn it as required. The mistake can be a hesitation (the subject tends to the wrong piece of equipment) or a wrong handling (the subject acts on the wrong piece of equipment and then makes a correction). Table II gives the proportion of mistakes on device #1 according to the configuration of training. The proportion is the number of mistakes per subjects' sample according to Table I. These proportions may be superior to 100% since subjects may do several mistakes. We add to the data the proportion of HP tools applied per subject. This appears to be a relevant data since the aim of the training devices is to succeed the water sampler with the help of HP tools. To obtain this value, the number of HP tools used by each subject has been counted, then an average value has been calculated for each sample of subjects according to table I, and finally a proportion has been calculated knowing that a maximum of 6 HP tools were expected during the task realization. Figure 6 draws the bar-graph corresponding to the results given in Table II.

The first obvious finding is that the work on the mock-up without any training just before taking the activity gives the poorer performance. Observations when performing the task in configuration A have shown that very few subjects thought about HP tools application. The data confirm these observation as we obtained for configuration A the less HP tools applied.

Table II. Subjects' efficiency according to the possible configurations.

Configuration	A = 1	B = 2-1	C = 3-1
hesitations (%)	117	67	40
wrong handling (%)	33	25	0
failure (%)	17	17	0
HP tools (%)	39	47	57

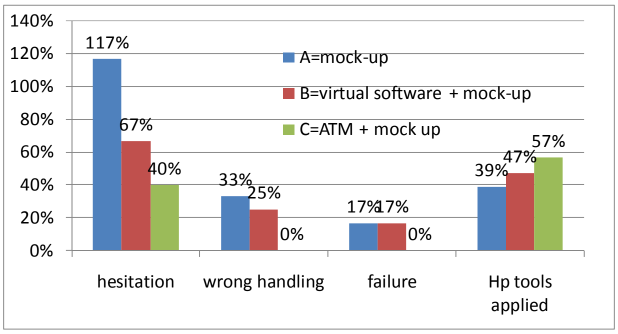

Fig. 6. Subjects' efficiency according to the task configuration.

Concerning the configurations with training, the results obtained show clearly that they improve the task performance. The main finding appears in the comparison between the effects produced by each one: while we could expect that the dedicated virtual device (#2) could give better results, in fact they are obtained with the decontextualized software focusing on HP tools, with 100% success, a significant decreasing of hesitations during the task performing, and the disappearance of wrong handlings. Furthermore, in the case of the decontextualized software training, we obtain the higher level of HP tools application.

Yet, it must be noticed, as said above, that the subjects were expected to be familiar with the reference situation task (device #1) and with the HP tools. This means that, in our experiment, we do not teach the task and the HP tools to the subjects: they already know them, have already practice them, and the pre-training helps to re-summon existing skills, making the workers more efficient. In this perspective, the Serious Game appears more as a pre-formating software rather than a pre-training software. The average time to perform the Serious Game task is 5 minutes.

4. Conclusion

Our experiment results show that a decontextualized software such as a Serious Game can improve workers performance using Human Performance tools (reliable professional practices) providing that an initial training has been achieved both concerning Human Performance tools and the task to be performed. The Serious Game is here a pre-formating (rather than a pre-training) software; this means that it helps to re-summon existing skills, making the workers more efficient, but it does not help to acquire new know-how or skill.
The potential gain is important from safety and economic standpoints: results show higher efficiency with simple virtual training and their cost may be lower than what has been used to date. Safer operating of industrial plants will be interesting for the operators as for the people living around such sites. Financially, this appears of low cost since we have demonstrated that a decontextualized software such as a Serious Game can improve workers performance using Human Performance tools. This means that the software does not need to be dedicated to the industrial device; there is no need, at this stage of the working activity, of a virtual software reproducing

strictly a refine context of the real activity. The pre-performing Serious Game may be applied for any task and requires short time. Yet, what is surprising is that all workers met in interviews ask for dedicated training devices to improve their practices. It means that Serious Games as a decontextualized but adapted training device is not expected by them a priori.

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Retraining for manager in the frame of HP program: the case of Chinon NPP

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Abstract
Reliable professional practices are important to insure the safe operation of nuclear reactors. Such practices become effective only within a managed framework. This implies managers' involvement in the field. In French nuclear power plants, specific training Is needed for managers as they have been for a long time in the field mainly to control, to check, to evaluate. We present here a focus on the managers' training within the framework of the Human Performance Program. Concrete exercises are described.

1. Introduction

Exploitation of nuclear power plants implies a high level of safety and of work activity reliability. The production division of EDF always tries to find organizational solutions in order to reinforce these lines (see for example : Le Bot, 2004 ; Fauquet, 2007, 2008). Since several years, a Human Performance Program has involved all the nuclear power plants of EDF, within one topic concerning the management in the field dealing with organizational problems.
The present paper exposes what is done on the NPP of Chinon to help the management to be effective in the field with this aim. It explains why this can be difficult and what kinds of changes it implies, and exposes the means which have been chosen, focusing on specific training sessions.

2. The industrial context and the Human Performance Program

Since several tens of years, studies have shown how much human contribution to safety of industrial facilities is important: safety cannot be only supported by automatic protection and control systems and a comprehensive socio-organizational approach of work activities must be managed at every organization level (Llory et al., 1988). Thus, organization and management of French nuclear power plants are involved in a Human Factor policy which evolves permanently with the main aim to enforce nuclear safety (Fauquet-Alekhine, 2012a; Lagrange & Desmares, 1999). The Human Performance Program is situated in this frame. It consists of several items among which one concerns the management in the field. A large benchmarking has been done (different countries, different industries) to identify especially: i) how can progress a safe industry by avoiding minor events? ii) what helps a worker to avoid minor events?

Why being interested on these two points? Because event analysis shows that majors events which concern safety are always a combined contribution of several minor events (by event, it is necessary to understand a gap between realized work and expected task; any event detected leads to a treatment (Fauquet, 2004, 2006) and is assessed according to the INES scale; quasi entirety is classified at level 0: "no importance from the point of view of safety".

Avoiding minor events is thus useful to reinforce nuclear safety as soon as they are identified: studies (Rasmussen et al., 1994; Leplat, 2006) have shown that progress could be made in common work activities, those which are made very often, and lead the workers to be used to their job (more efficient) but also used to the risks (they could be in routine conditions and not see them). Benchmarking has shown that Anglo-Saxon industries are using some specific professional practices (they are also said Human Performance tools, or HP tools) to avoid such minor events (see for example Fauquet, 2009; Fauquet-Alekhine, 2010; Fauquet-Alekhine & Pehuet, 2011). The nuclear division of EDF has selected 6 of them to be applied during activities.

One of the problem is that those professional practices, if they are daily applied by a lot of Anglo-Saxon workers, are not part of the Latin culture, among which French industries, and of course, nuclear power plants. Furthermore, these HP tools seem to be more easily applied in a given industrial environment, according to a given kind of management culture. On French nuclear power plants, since several tens of years, the management was involved in the field mainly for verification, control, and evaluation. The risk that was identified by the nuclear division of EDF was that, in such a context, the HP tools could become a mean to overcome organizational defects rather than make the activities more reliable.

It has been decided to help the management to change its work in the field. To deal with daily organizational

[*] This work has been presented at the *IX[th] Human Performance meeting of WANO*, 21-26 nov. 2010 - Oldbury - UK
http://www.wano.info/

defects and help the teams in working situation, a corrective action program has been launched to manage minor events and their treatment, and a management program has been engaged on all the NPP of EDF (Colas, 2001; Theurier, 2010; Fauquet-Alekhine, 2012b).

3. The management program in the Human Performance Program

First, the management is involved in an initial training session which spreads out over several months in three steps.

The first step is an informative session of two hours, during which the head manager of each department will brief his managers about the aim and the needs concerning the manager in the field within the Human Performance Program. This is the time for the head manager to make his staff understanding the gain expected by a new way for the management to be in the field: not only for verification, control, and evaluation, but also to deal with daily organizational defects.

The second step is a training period in the field, in order to help the manager to adapt this practice and attitude if necessary.

The third step is a meeting with other managers, to share about difficulties and solutions compared to what is expected.

Then, there must be a permanent motivation of the management to reach the goal. This is done by:

- the head management which reminds the expectations concerning the management in the field,
- the event analysis used to remind the meaning and purpose of the "management in the field" expectations,
- the view through some indicators,
- a feedback through the analysis of what they do,
- the training or retraining support used to remind the meaning and purpose of the "management in the field" expectations, to remind the expectations themselves, to help the manager to be in the field, and also to remind what is expected from the workers concerning the use of HP tools because.

This permanent motivation has very soon been identified as a necessity, because a manager who is used to been in the field mainly for verification, control, and evaluation, is quickly going back to old habits.

4. The management program and the specific training and retraining support

On the NPP of Chinon, we have built by time some specific pedagogical exercises concerning the management.

Two full scale simulators are used to help them practicing the HP tools, and them to observe themselves in the field.

Two simulators, a software piloting simulator and a pocket maintenance mock-up facility, are used in classrooms for the same purpose.

Additional specific exercises are used to help the manager in the field:

- Exercise for a Simple construction for HP tools,
- Exercise for a Complex construction for HP tools,
- Exercise for a Team activity with 2 kinds of management.

Exercise for a Simple construction for HP tools

This exercise needs thirty minutes, including discussions in debriefing.

The pedagogical aim is to hold the manager to see how small organizational details can spoil the efforts of workers in the reliability of activities.

Managers are asked to work in groups of two to three persons. Each team receives an operating mode, and a set of seven to ten wooden pieces. In ten minutes, they must build together a four pieces frame. The operating mode is the same for every team except the title.

At the end of the ten minutes, some of them are exposing something which looks like a tractor, and the others have something which looks like a modern art construction (Fig. 1).

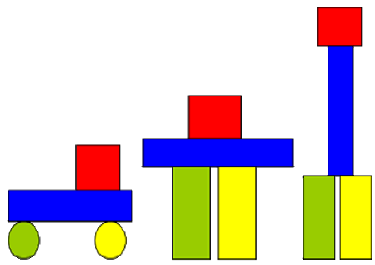

Fig.1. Samples of constructions proposed by the participants involved in exercise Simple construction for HP tools

We then explain to all of them that the operating modes where the same, except one detail. They exchange the operating modes and usually can not see the difference: every body focuses on the lines of the operating mode, forgetting the title. The demonstration is done: managers, as workers, forget to watch what will give them the meaning of the work activity (the title) as soon as they think that they know what is the document about.

The pedagogical objective is to lead them to understand that one of the management tasks for Human Performance is to make the operating mode effective and reliable, for the workers to apply HP tools in good conditions. This must become a general conclusion: they must watch the organizational defects for the HP tools to be effective.

Exercise for a Complex construction for HP tools

This exercise needs 1h30 to 2h, including 1h to 1h30 for discussions in debriefing.

The pedagogical goal is to help the manager to feel the organizational difficulty to apply HP tools and to know how to observe HP tools.
The staff of a department is gathered is a room in which they must build the first circle of Stonehenge (Fig. 2a), picking up in a set of wooden pieces some of them (Fig. 2b), according to an operating mode. Figure 2b is not shown to them; they see it only after the exercise.

Fig. 2a

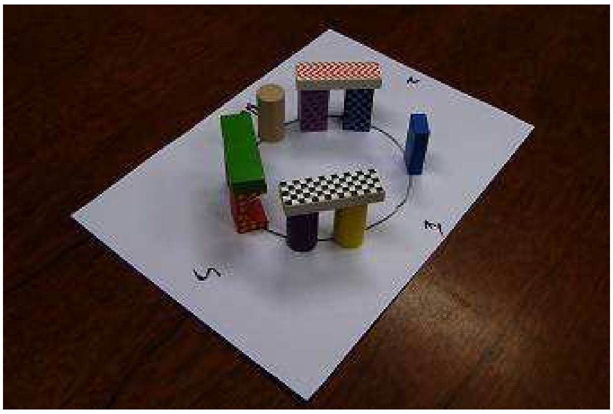

Fig. 2b

Fig. 2. Complex construction for HP tools – a) A cultural goal to make sense –b) The result expected

The operating mode does not exist as a whole: everyone will receive one instruction, and the information will have to be analyzed together before application (pre job briefing and time breaks). To conduct this analysis, a leader is design (usually, we chose the boss of the team). Four of them will be observers, but they keep information each that will have to be transmitted to another person. This implies that four other persons will have to ask this information (reliable communication). Four other managers can each read information kept on a paper: for each one, this paper is kept in another room; they can go there and read it, but must leave there the paper to bring back information in the main room (self-control and reliable communication). To build the circle, one piece is part of another construction: no mistake must be done about the selection of this piece, because in case of mistake, this piece is lost (time break and peer check).
The number of persons can be change for the purpose of the need.

At the end of the 30 minutes, the observers have a lot to say. The debriefing of the session help the managers to understand by the feelings and the acts:

- the gain produced by the HP tools,
- the complexity of acting with pertinent and effective HP tools,
- HP tools are not always easy to observe, even if applied,
- the observation of organizational defects (including the management of the team) and the clear identification of what is a main defect, and what is a minor defect,
- the necessity of discussing solutions with the workers concerned by organizational defects.

The session debriefing is conducted like the simulator training session (Fauquet, 2008; Fauquet & Frémaux, 2008; Fauquet-Alekhine & Pehuet, 2011), or like the event analysis (Fauquet, 2006).

Exercise for a Team activity with 2 kinds of management

This exercise needs 2h, including discussions in debriefing.
The pedagogical goal is to help the manager to feel and to understand what produce the manager's attitude on the team, make an analysis of his own attitude in the field and of the one of the department management in the field, and think about what can be changed.
The first hour is an exercise and its debriefing.
Managers are asked to work in groups of two to three persons, in different rooms (no contact). Each team receives an oral operating order, a set of materials (one pencil, one board on a paper, a draft paper, a pocket calculator, a set of ten invoices). In a quarter of an hour, they must write on the board paper, on each line of the board (one line for one invoice) :

- the name of the society paid,
- the things provided,
- the amount of taxes,
- the total amount of the invoice.

The final goal of the exercise is to calculate the total amount of taxes and the total amount of the invoices, and to compare them.

Several problems occur:

- the pencil does not work,
- the pocket calculator has no batteries,
- some invoices do not show explicitly the amount of taxes which must be calculate,
- some invoices include different taxes rate due to the things provided, which implies some specific calculation, and some adaptation of rules to fill the paper board (the manager's help will be needed).

To lead the teams, there are two managers, M1 and M2, who are trainers in fact. M1 is fully concerned by organizational problems. M2 is mainly concerned by the respect of prescription and rules. These managers are outside the rooms where is working the teams, but can be called as soon as it is needed.

Of course, because of the problems listed above, the team will ask help for material and for the work understanding.

When M1 (organization) comes, he always brings soon a solution, or a suggestion, while M2 takes time to come, then to produce the solution or give the information. And every time M2 comes, he makes some remarks concerning the job: everything must be written exactly in the blocks of the board, the name of workers on the form must be the surname followed by the first letter of the first name, the invoices must be recorded on the paper in alphabetic order (which is useless), and so on.

The debriefing of the session helps the managers to feel and understand what they produce in the field: the general comments are as follows:

- for M1 (organization) team, the task is not interesting but can be done,
- for M2 (prescription) team, the task is boring, the manager does not help, and soon, he was not welcome.

The "workers' attitude" adopted by the managers during the exercise is always:

- for M1 (organization) team: they are pleased to see the manager ; "we work all together : the team includes the manager",
- for M2 (prescription) team: "at first, try to do our best, then, when manager coming, he can speak...we laugh after".

The debriefing concludes that people work for a result, a company, and a man (the boss). The manager's attitude in the field contributes to built workers' behavior and results. The demonstration of what is gained with a management concerned by the organization in another way than verification, control, and evaluation, is done.

The second hour consists, for each manager, in thinking about their own way to be in the field according to what has been said and discussed during the previous hour.
The managers are asked to explain how they see themselves in the field, and what they can hear from the team about their presence in the field. They discuss about what they would like to do according to what is expected of their head management. The discussion usually concerns paradoxical injunctions: the head management seems to ask them to be in the field for the detection and the treatment of organizational effects, but at the same time, ask them to feel some indicators concerning verification and control. They try to know how to deal with job meetings, consuming a lot of time. Managers explain their need of training, because of their old habits which engage them to be in the field for controls. It appears clearly that we have a work to do, from an organizational standpoint, in order to bring more coherence between on one hand, the expectations of the head management and the job meetings for which the management is required, and on the other hand, the management in the field for the organizational defects.

5. Conclusion

The French nuclear power plants of EDF are involved in a Human Performance Program which aim is to reinforce the safety of nuclear exploitation. Among the means used to reach this goal, the management in the field to deal with organizational defects is a main one.
Efforts must be done, from an organizational standpoint, and for the head management expectations, in order to help the managers in the field. Among those efforts, we have the training of the management, a permanent involvement through self-analysis done periodically, and a training supports renewed, sometimes by the means of out-context situations to help people to think the situation disconnected from the usual constrains felt in the daily job.

While the Human Performance Program is proceeding, some significant progress has already been observed on the exploitation of nuclear reactors of the French company EDF. But it needs time...

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The structuring effects of tools in risky industrial work activity: failures and solutions

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http//hayka-kultura.com/larsen.html

Abstract

Professional training for risky professions involves procedures and guidelines requirements. The use of the tools derived of this need sometimes have a so strong structuring effect that the user is unable to do otherwise than going to the failure.

Experiments have been conducted in order to determine if, within an industrial working population (*N*=57), whether there could be a profession or an academic training making the subject less weak concering the structuring effect of the tools.

Results have shown that the solution does remain neither in the profession nor in the academic training, and that tools must integrate this possible weakness of the intervener. Further experiments are planned to assess the effect of confidence and of global control.

1. Introduction

Exploitation of risky industrial plants implies a high level of safety and of work activity reliability. The production division of EDF always tries to find organizational solutions in order to reinforce those lines (see for example: Le Bot, 2004; Fauquet, 2007, 2008). Since several years, a Human Performance Program has involved all the nuclear power plants of EDF, within one topic concerning the management in the field dealing with organizational problems (Fauquet-Alekhine, 2012). Nevertheless, with all constrains under which workers and managers are submitted, due to diverse fields such as safety requirements (Buessard & Fauquet, 2009), production, economical competition, skills drain due to aging workers and renewal staff… work activities analysis show that, in given working situation, workers can be involved in a structuring effect of the tool used to perform the task. Observations have shown that sometimes workers could be involved in a human error or a deviation leading to a major (or significant) event even when they were updated regarding the task, were experienced, were well informed about the activity, knew all about the job, were not too much self-confident. Indeed, nothing could explain the result except making the assumption that the tools used to perform the task under time pressure could have led them to the event. We thus thought the need that the tools used by workers and its potential structuring effect on the activity realization had to be investigated. We made the assumption perhaps a given category of workers, or a given category of academic background, could reduce the structuring effect of the tools.

The Macmillan dictionary suggests that a tool may be a piece of equipment, usually one that you hold in your hand, that is designed to do a particular type of work, or something that you use in order to perform a job or to achieve an aim (for example, speech is a tool of communication), or someone who is used by another person or group, especially to do a difficult or dishonest job.

Making the list of possible tools, we concluded that it could be the physical objet that extends the subject to transform the environment (e.g. carpenter's hammer), but also a method that helps the subject to transform the social world, the organization, the attitude, the behavior (e.g. the professor's books for teaching, the psychologist's protocol, Human Performance tools for the field worker). A tool may be thus external to the subject and to the object or internal to the subject. The essence of the tool can be physical (a hammer) or psycho-social (a method, a protocol, a procedure,…) or cognitive (a way of thinking) but can anyway be materialized as a physical tool by being written on paper (procedure, book). The transformation produced can be physical (making a roof) or psycho-social (obtaining new behavior, new organization, new consumption habits).

The tool being an important mean of the work activity in industrial context, and the potential structuring effect of tools leading to major event being observed, we decided to conduct experiments in order to determine whether or not a given category of workers, or a given category of academic background, could reduce the structuring effect of the tool. The assumption that some professions or academic background could have such an outcome was made after specific training sessions involving groups of workers taking psycho-technical tests: it appeared for example that some professions were more successful taking a test involving the Stroop effect than others.

2-Materials & Methods

The study has been conducted with subjects (*N*=57) working on the nuclear power plant of Chinon. Different categories of jobs have been chosen in order to:

* This work is part of what has been presented at the *Xth WANO Human Performance Workshop*, Malmo, Sweden, 2012. http://www.wano.info/

- determine how the tools used to perform a work activity can be structuring and lead to the error,
- determine whether a socio-professional class or academic training can question the structuring effect of tools,
- understand palliative measures to the structuring effect of the tools and at what levels (within the tools, external to tools or activity or intervener).

We are thus studying how to avoid deleterious focus-structuring of tools (including modus operandi) in work activity.

The professional categories chosen were:

- executive manager,
- charter engineer manager,
- ex-technician manager,
- nuclear reactor pilot,
- technician,
- department assistant,
- service sector job.

A last category was added, external to the industrial context:

- student (9 to 14 yo.).

It has been added in order to appreciate the possible influence of the formatting effect of the academic training or of the professional training.

The test is called "Letter-test". It consists of a work activity done in a minimum of time. In fact, less than 5 minutes is necessary. Objective of the activity is to count up on five boards with three rows of letters each, the number of letters which the size (height) is less or equal to 5mm (Fig. 1 a). To do this, two different tools are proposed: a flat ruler (triple classic transparent decimeter) or a mask preformatted for the size of the boards (Fig. 1 b), with an opaque black area pierced with three rows of eight windows each. The mask is presented as developed especially for the work activity with a calibration of the height of windows said equal to 5mm: if a letter is seen entirely in a window, it must be recorded.


a


b

Fig. 1 a &b. Letter-boards and mask used for the test relative to the structuring effect of the tools.

The boards are seen one by one; whenever the board n+1 is given to the subject, the board n is taken by the experimenter.
The subject is informed that the Letter-test is timed (time pressure), and s/he must choose one of the two tools proposed initially knowing that s/he can come back on this selection as much as s/he wants. All dialogues of the experimenters are written so that they give the same information as much as possible with the same words, same expressions for each subject.

For each analysis of a board, the results must be deferred on the supplied grid (Table I).

Table I. Results grid for subjects taking the Letter-test.

Board →	1	2	3	4	5
Line 1					
Line 2					
Line 3					

The specificity of the Letter-test lies in the fact that all the boards have a similar structure (3 lines and 8 letters per line, all positioned at the same place on a board) except the last board: the board #5 has 9 letters per line, the eight first letters positioned as on the four previous boards. But the mask is sized to 8 letters per lines: so it blanks the letter #9 of each of the lines of the board #5.

Ethics: all of the data collected is treated statistically. No personal data is collected or recorded. Subjects do not broadcast on their side any information concerning the test. Only socio-demographic data, results and observations are recorded.

3-Results

The gender is not mentioned because each profession induces this proportion. For example, the "department assistant" category is female 100%, and the "executive manager" category is male 100%.
Age and experience have been represented as large as possible: it is not expected here a representative sample of the population of the site in terms of respect of proportions, but in terms of different profiles.
This sample is to identify whether or not a population stands another in dealing with the three lines of the board #5 letter #9, i.e. by implementing a particular approach, by deploying a special reflection.

Analysis of the data shows that, among the adult population of the sample working on NPP, no population is pointed out, neither by the profession, nor by training. Indeed:

- only 6 people over 57 deal with the letter #9, that is 11%,
- among these 6 people, there are 3 students, which gives 3 people out of 50 over the adult population, which is 6%.

Professional profiles dealing with the letter #9 are:

- engineer - manager (1),
- operator (1),
- technician (1),
- student (3)

Academic profiles dealing with the letter #9 are:

- doctor (1),

- charter technician (BEP degree) (1),
- university charter technician (DUT degree) (1),
- student (3).

On observables, we see that:

- 39% of subjects spontaneously implement a Pre-job Briefing (PjB) by questioning and reformulation of what is to be done, all categories combined,
- 33% perform initial review of the conditions of the work activity in action; the control concerns especially the adequacy of the mask with the objective of the task; however it is implemented at the beginning of the activity only,
- 23% applies a specific method by removing such as vertical boards in rising or raising regularly the mask.
- 12% choose the ruler at the beginning of the activity and not the mask, different percentage of those dealing with the letter #9 because some of them change tool during the task performance,
- 11% have treated the letter #9,
- none was aware of the presence of an additional letter by line on board #5.

These results are represented in proportion of the sample on Fig. 2.

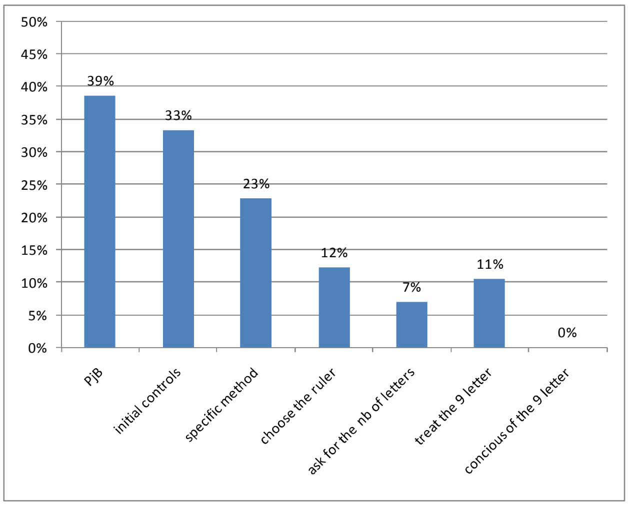

Fig. 2. Proportion of subjects having a specific behavior whilst taking the Letter-test.

The correlative analysis between results and observables indicates that:

- 100% of the people who have chosen rule deal with the letter #9, and 100% of those opting for the mask do not,
- 100% of people who have dealt with the letter #9 are not aware of the presence of an additional letter by line on board #5.
- 83% of people who have treated the letter #9 performed a PjB.
- 50% of the people who treated the letter #9 initiated prior checking to the realization of the task. But 100% of adults who have dealt with the letter #9 performed prior checking to the achievement of the task.

These combined behaviors are presented on Fig. 3.

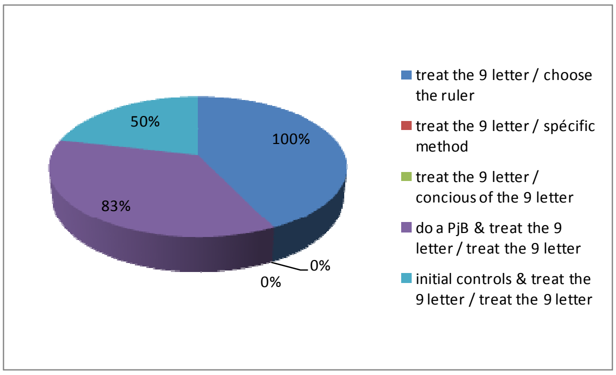

Fig. 3. Proportion of subjects having combined specific behaviors whilst taking the test.

To these data are added findings coming from observations when carrying out the activity and interviews in debriefing with the subjects. In particular, it appeared a priori confidence in most cases between the subject and the experimenter, which was not involving the subject to doubt about the quality of the mask, and therefore did not engaged to carry out or to deepen the initial control of the mask.

Observations in phase of realization of activity showed how the tool is structuring and focuses attention on specific informative clues, helping to achieve the goal, shadowing the peripheral indices. Thus, some subjects have implemented methods that might have revealed the presence of the letter #9, but did not see it while they had it in front of the eyes:
-Example 1: Some subjects (less than 10 cases) fit the mask for all the boards by raising the mask several times to see the letters under the mask. Most of them are looking for the letters matching within the windows. They do not note letter #9 while visible.
-Example 2: The subject comes to the board #5, put the mask on, counts letters, and has a doubt concerning the last letter that appears right of the line #1. It is a 'b'. He removes the mask, takes the ruler and measures letter #9 which is a 'o', puts back the mask on, recounts the letters and does not notice that the last window of the line #1 gives a 'b' and not a 'o'. (EMT01)
- Example 3: The subject has chosen to align the mask not on the upper cross of the board, but on the right column of the lines: for each board, s/he puts the mask by adjusting right windows on the right column of the letters, column #8. Comes to the board #5: he does the same, and aligns the right windows of the mask on the right column of letters, here column #9. This produces a visible shift for the experimenter-observer both for the crosses and the format paper. But the subject notes nothing and therefore deals with letter #9 but not letter #1 (in statistics, this case is registered as having not dealt the letter #9). (EMT04) (Fig. 4)

Fig. 4. Example of shift of the mask put on the board #5: we can see in the upper left corner the shift of the mask cross compared to the board one. We can also see the shift of the transparent mask over the white paper of the board.

-Example 4: Some subjects (4 cases) performed an initial control which led to accept the mask using only the middle line windows. Their goal is to work with a dedicated tool (which works fast) but reliable: considering then that the top and the bottom window lines of the mask are too big, they apply the mask on the boards shifting the middle window line on each line of the board. Doing so and arriving at board #5, they make visible letter #9 of lines #3 and #1 in offset from the windows of the mask (CEM09, P02, P04, TP08 (line 1)) (Fig. 5 a & b).

-Example 5: A subject takes the Letter-test in a room, facing a window, and decides stalling the mask maintaining the boards vertical. A posteriori, it is verified that letter #9 of the board #5 are slightly visible. But the subject does not see them.

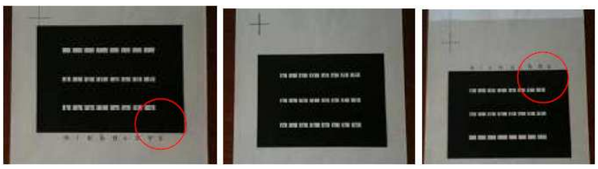

Fig. 5 b & c. Examples of shifting of the mask when using only the middle line.

4-Discussion

Interviews with adults indicate that time pressure induced by the announcement of the activity timing expected as short as possible lead them to choose the mask. They think that this "tool developed especially for this activity" will save time, which is true since the mean time of realization using the mask is about 3 min. while about 6 min. with the ruler. They therefore prefer the speed.

Subjects dismissing the mask for the ruler have all made a prior control of the mask and concluded that it was not reliable.

However, students have another approach. Their rejection of the mask is not due a qualification examination of the mask, according to their explanations in debriefing and the observed facts: none of the students has done such initial examination. What they prefer is to control the situation rather than the speed. The rejection of the mask is induced by the inability to see what is hidden, the choice of ruler is induced by the familiarization with this tool while the mask will be used for the first time. Thus, the time constraint is not the same value for this population covering the age 9-14 years.

5-Conclusion

The findings are the following:

- No population of NPP professionals stands another in dealing with the letter #9, i.e. by implementing an approach, deploying a special reflection.
- The proportion of professionals of NPP dealing with the letter #9 is very low (6%), compared to that of students (43%).
- The population distinguished is therefore the students (9-14 years). They favor control of the situation rather than gain of time: they want to be efficacious rather than efficient. However students have not yet been confronted with the imperatives of the world of work and productivity: the adults are and have learned, were formatted to become efficient (efficient in a minimum of time and resource). However, any non-professionals of NPP population can do better than a professional, because to work on NPP (as in any industry), there is a need to professionalize the newcomer, who therefore becomes, whilst learning to be efficient, very sensitive to time-control assessment.

Not having identified any industrial population distinguished from another, and not identifying any particular method related to the profession or the academic training, it must be sought a solution to cope with focus-structuring effect by the tools. For the moment, it is clear that the solution lies in the reconstruction of the tools: it must be the elements that will allow the person conducting the work activity of awareness of this possible focus. However, the solution cannot always be intrinsic to the tools: indeed, a hammer will be a hammer while a procedure can be adjusted, a working method can be adapted. In particular, an overall control at the end of work activity can be achieved, which was not allowed in the proposed test. To assess the effect of such control, other samples of subject will be met.

In addition, in the tests, encountered subjects showed relative confidence in the experimenter. A sample of subjects for which the confidence will be reduced will be also met.

Thus, we will see if one of these opportunities helps to improve the results.

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Chapter III

Simulation training

Simulation for training pilots of French nuclear power plants

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Abstract

We here present the simulation training policy for French nuclear reactor pilots. Training sessions are described. Advantages and drawbacks are discussed. The trainers' interactions are commented. Tools for transference of know-how and skills development are presented. As a conclusion, perspective of new training tools are suggested.

1. The context: Industrial facilities and pilots

The operation of nuclear power plants requires a high degree of control, whether in terms of operating or maintenance, and whether in normal or accidental situation. It concerns security and the health of populations, and therefore the possibility to maintain the nuclear sector in the energy market. Nuclear operator must thus be able not only to maintain its know-how but also to update and to adapt to the new requirements, which can intervene at the level of safety or security, regulation or legislation (Buessard & Fauquet, 2002), or economy. These imperatives are of two types:

- External: nuclear safety requirement changes that the operator as the nuclear safety authority keep on strengthening,
- Internal: corrective actions from event analysis essentially done by the operator.

Several domains are worked out to ensure these imperatives. The technical aspect comes in the first place since the industrial purpose is to run a technical system: this dimension receives the design engineers' attention from the construction through the operation to the decomissioning of a plant. The organizational aspect comes in second place, with a permanent desire of analysis and adaptation of the organization taking into account human in any dimension, since the industrial purpose is also to operate a socio-technical system (see for example: Lagrange & Desmares, 1999; Fauquet-Alekhine, 2010a). Many other fields are operated permanently, including those implemented to meet the capacity to develop and maintain expertise (Fauquet, 2003 and 2004): for this aim EDF uses nuclear reactor piloting simulators. Control rooms are reproduced in scale 1 (said "full scale simulators "), and calculators allow real-time simulation of the physical parameters of the installation. The choice of such a teaching tool is motivated by a dual need:

- creating closest situations of the reality of operations,
- leading a team to pilot a complex technical system collectively.

In this perspective, the full scale simulator has demonstrated its added value for nuclear industry and well before that for aviation.

The actors of the simulated situation are the pilot team members and trainers. An operating team of nuclear reactor is generally composed of 15 individuals (case of the 900 MWe reactor type) who operate a pair of reactors and associated equipment. The taking of position is a 3 x 8. The mission of the operating team is to pilot the reactor according to the electricity producing demand from nuclear energy while ensuring the safety of facilities. In the team, four to six people are in charge of piloting, the others being attached to the manipulation of pieces of equipment on the installation directly.

2. Genesis: technical and pedagogical design

2.1.The simulator

There are different types of piloting simulators: full scale simulators and part simulators.

Part simulators represent portions of the control room, and focus on a basic part of the installation that pilots must learn and know before being involved in the whole operating process.

Full scale simulators consist of the control room, replica of the operating reality, a calculator and a control panel from which trainers manage the simulated situation. This panel is closed-glass without color and with digital video system connected to several cameras that allow various views of the control room, with a capacity of zoom such that reading from a sheet of paper is possible. All of the views of cameras are recordable and available later in the debriefing room. This video system presents an undeniable added value and is subject to a strict ethic: any image is deleted after the training session, and the use is limited to the situation actors only.

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2.2.The scenario

The only simulator does not reproduce a work situation in which operating team will be able to evolve in a context which is the most realistic possible, i.e. reproducing the better the reality of industrial operating. The simulator is only a support tool recreating an environment and permitting the interactions between actors and the industrial process. To create a simulated situation, it is necessary to dispose of prepared scenarios that engage actors in action. These scenarios incorporate the input parameters for the simulator calculator and input parameters to deliver to the operating team. This allows to introduce the input data concerning the work situation which each one is about to live on the simulator. It is also the time to propose a technical chain of the process during the simulated situation. The whole is coordinated by the trainers.

2.3.The trainer

What the trainer is in ability to do during the simulator run (as during the session debriefing) is highly dependent on his professional experience. The trainers have various career profiles. Some of them are coming from operating professions. Being from these professions gives legitimacy at once in front of the persons in training: This makes more easy technical discussions and this is felt by the trainees, and it allows the trainer to support discussions in debriefing by the narration of experienced examples, full of meaning for the actors, and appreciated because s/he thus facilitates the understanding of the topics discussed. In addition, this provides a certain attraction to the exchange, due to the anecdotal character of the story. For newcomers on a position as an trainer, computer databases containing stories of events will be investigated upstream training sessions. This data base is a enjoyable tool even for the experienced trainer who sometimes would tend to stay on her/his own experience, which, even rich, therefore will take all the benefit of recent operating experience feedback.

2.4.Reference / simuilated situation

From a reference situation, the scenario develops the simulated situation by reducing the variability of the context to emphasize what is necessary to achieve educational goals.

This reduction in variability (i.e. the simplification of the situation simulated from baseline), is fundamental in the pedagogical approach, because it provides the means for the pilots to focus their cognitive resources on some of the difficulties brought by the script directly in connection with the pedagogical objectives. Sometimes, pilots are complaining about being "too far from reality", but this may be a necessity in the first place.

2.5.Training phases

All of which is implemented in simulated situations and debriefing is essentially the work of research by Pastré, Samurçay, and Plénacoste, from 1996 to 2001 (Klein et al.,) 2005. Béguin and Pastré (2002) describe the conceptual perspective of situations of simulations and debriefings (see also Pastré, 2005) which was completed by Fauquet (2007). In short, we must remember that different modalities of work exist on simulator based on the objectives sought; for example:

- initial professionalization,
- recycling,
- accidental procedures,
- development of know-how within specific sessions called “involving situation” (“mise en situation” in French).

The initial professionalization is itself decomposed in different phases: discovery and appropriation of the simulator, basic operation of the facilities, operating in situations with technical failures. This progressive approach is fundamental because it allows to place trainees in good conditions for learning: recent work showed that gradual approach for crisis simulation scenario placed most of trainers in a zone of cognitive disorder (Fauquet-Alekhine et al., 2011a & 2012).

2.6.Training session debriefing and professional practices improvemnt

To achieve these goals, analysis of practices methods are used. This enables to re-examine what is done by the team as what is not done, what have been the thrust or not, with a perspective of potential transformation. This transformation can affect the individual or the collective, but also the work organization in a non-simulated situation.

However, any situation does not necessarily imply this type of transformation. Sometimes, the collective analysis of the work activity points practices recognized as effective by all actors (operators as trainers). The added value is therefore more than a transformation, but also a conscience making contributing towards the anchoring of these professional practices.

In this type of exchange, the trainer leads the trainees to re-examine what is accepted in practice, and encourages pilots to define their personal style. It allows them to (re) become aware of what they are implementing in the work activity, and eventually make it available for others: how to better transfer to others what we are aware about?

The trainer can also lead pilots to speak on the usefulness for him to adopt such a practice. This leads them to become aware of their practices, and possibly to think about them for other situations (Fauquet, 2005a). The consciousness, individual first, broadcasts in the collective to be integrated within a professional style.

The sought effect in the session debriefing is the distancing of the pilots with their action in the simulated situation they lived. To do this, the enveloping position of trainer, distant observer in a simulated situation, is valuable assistance. This situation distancing facilitates the understanding of the pilots' intellectual approach of the situation, individually and collectively, and must permit the re-work, i.e. allow re-thinking in order to transform. This distancing from the trainer also promotes the observation and analysis of the interaction human-process, interactions between individuals and also the individual and collective contributions (or non-contributions) to the action in the situation. The result is a potential transformation of the actions, interactions, and contributions.

The debriefing refers to the methods of work activity analysis developed by Yves Clot (Clot et al., 1999, 2000, 2002; see also Fauquet, 2005b and 2006a; Fauquet-Alekhine & Pehuet, 2011b) and is similar by some of its aspects to the Crew Resource Managements done by airline companies.

2.7.The training session structure

Taking a simulation situation by an operating team is carried out on average on 3 days, each day that can be broken down according to the objective of the training:

- A run on the simulator and a debriefing in classroom. The briefing lasted less than 30 minutes. The "run" refers to the fact of taking the simulated situation, with a time length of 2h30 to 3h. The debriefing of meeting lasts 2h30.
- A run of 3h followed by a debriefing of 3h separated by a 30 minutes break.
- A debriefing of 3h followed by a 3h run separated by a 30 minutes break.

It must be kept in mind that a simulated situation has meaning only by combining adapted run time/debriefing time, where " adapted " implies that debriefing time should give time to discussion for what is done during the run. In other words, believing that a good simulated situation is one that favors the time of the run on simulator is an mistake.

3. Extension: studies, assessment and maintenance training

Beyond initial training, development and learning of new methods (Fauquet-Alekhine, 2011c), the simulator is a place of study (see Le Bot, 2004; Fauquet, 2004b, 2006b; Fauquet-Alekhine, 2010b; Fauquet-Alekhine et al., 2011a and 2012): when professional practices are established and anchored in the professional gender, any organizational modification or change proposed by the management may be studied and assessed prior to application. It concerns the implications of such decisions in terms of potential consequences on the key parameters such as safety, security, and production. For example, what is the influence of such additional alarm, what consequence if using such standard of communication, what added value with such technical change for the quality of the industrial operation an dfor the safety?

Training, study... and of course evaluation! Since more than ten years, the capacities of the workers trained to operate reactors are subject to initial assessment, but validation of capacities renewal is implemented only since 2005. It is a matter of capacities validation, not skills validation. It is clearly agreed in the pedagogical requirements that skills cannot be validated in simulated work situation. Validation of skills is therefore for the hierarchy of the persons concerned. On this point, it should be noted the difficulty encountered by the company to implement this system of continuous assessment: management decision has been confronted at the beginning of the Human Performance Program to a tough opposition to a certain category of personal strongly assisted by union trades. One of the lessons from this situation is that, to avoid this kind of conflict, the integration of the ongoing evaluation by the simulation must be very quickly integrated into the training organization, otherwise taken daily rehearsals can delegitimize the simulator as an assessment tool.

Progress induced by simulator training was consequent enough for the Nuclear Production Division of EDF management to recently make two major decisions, heavy from organizational and financial standpoints, but successful in terms of skills development. At the end of the 1990s, while the nuclear power plants of EDF had several simulators on less than five French sites, it was decided a new distribution and the staffing of each of the twenty French nuclear sites of a full scale operating simulator: the investment has been considerable. Then in 2006, the head management chose to expand this educational action in other professions than operating and piloting. While there were full scale mock-ups for intervention and maintenance personnel, it was decided to rig each nuclear plant of a full scale maintenance simulator in so-called "chantier école " structures: a space of more than 200 m^2 reproduces an industrial environment integrating different pieces of equipment for intervention such as ventilation, pump, valves, capacity, exchanger...with or without fictive radiation protection measures.

Quantifying the results induced by such actions is difficult because they are always part of an action plan. What can be rated is the result of all of these joint actions. To give just one indicator, since 2006, the number of automatic scram for French nuclear power plants has been reduced by more than 20%, which is considerable.

4. The advantages and disadvantages (limits)

4.1.The several-days training session

Among the benefits of training on several consecutive days, we can point:

- The existence of a time of integration from one session to another, a time of reflection. The briefing, taking place just before the simulator session is beneficial for any learning. The production of the previous session remains present in the trainees' mind and is reactivated by the trainers at this particular time. This re-actives the pilots' attention on items selected in the debriefing during the day before.
- The possibility of a progression on these days; for example:
    - D1 is to analyze a given problem according to "solving problem " method and to identify the areas for progress,
    - D2 is to try to implement what was decided in the previous debriefing.

- o D3 is to work the transposition to another situation,

This time of briefing just before the run on simulator helps anchoring new practices thought during the debriefing of the day before.
From the standpoint of learning and transference in non-simulated operating situations, a several-days simulator session is a real added value.

4.2.Fast kinetic and freeze option
The simulator also allows to vary the kinetic of physical phenomena in two senses: for the dilution process that would take several hours for example, the trainer is able to accelerate the simulation to fit the scenario in time limit for a run of 3 hours; similarly, for something fast, it is possible to "freeze" the simulator, i.e. freeze the industrial process in the state so that the pilots can take the time to think about what is going on, and the consequences of their actions or their non-actions.

If the benefit of such functionality of the simulator (adjust the kinetic of phenomena) is immediately visible, it must not be forgotten the possible drawbacks this can induce. Increasing the speed of the physical phenomena does not allow pilots to work the result of slow kinetic. For example, the reality of operation induces long waiting periods during which the vigilance may diminish to the point that the installation check-up by the pilots loses efficiency: a pilot must be able to work this problem and this is not done if the simulator is accelerated. By contrast, freeze the simulator does not allow a pilot to work and try to catch up with the immediate consequences of an inappropriate action. Also, vary the kinetics of physical phenomena is not appropriate for the sessions called "involving in situation". They are adapted to the simulator sessions at technical learning phases (see section 2.5).

4.3.Transference
To help trainees, trainers follow the training evolution from one to another by a FAP system (“Fiche d’Aide à la Progression” in French), a support sheet for improvement written jointly by trainees and trainers. They are individual, given to each, and must ensure continuity of training on the simulator. For some training, a contract of collective transference is written at the end of the 3 days. This document is the property of the operating team. Trainers help in its drafting. It gathers all the important points observed during the session: good practices of the team on which they can rely in their activities on a daily basis and the work axes to improve. Must only appear on this document the facts and findings observed and recorded by the team. The team must feel free to use it or not. Some teams incorporate the contents of this document in their team project, or use this document as a specific theme on a day dedicated to the organization analysis of the team.

4.4.Physical separation
The physical separation between trainers and operating team offers several advantages: it promotes the involvement of actors in the situation, allows a dialogue between trainers without disruption or interference with the actors of the team, and encourages taking notes for the trainers.

4.5.Trainers’ background
One of the counterparts for an trainer coming from an operating or maintenance profession is that s/he can be engaged in technical discussions during the debriefing. The difficulty is then to know how to keep the distance necessary to not fall into such a trap. However, the solution cannot be the opposite, i.e. choose trainers who do not have such experience, as the job requires access to a legitimacy which will then not be acquired a priori. There is a need for the trainer not coming from the operating professions to know a minimum of the technical basis of these professions. S/He can win legitimacy by the use of techniques or methods appropriate to help actors to analyze their practices by her/his questioning. The fact that s/he is not skilled in the art of the professions gives opportunity for a relevant and productive questioning of the trainees.

4.6.Trainers’ training
When used by professionals of training, the training simulator is a remarkable tool. But as we have seen, the technological tool is effective only in connection with scenarii designed and built according to specific pedagogical objectives taking into account specific precautions. There is therefore a need of competence. Having this competence is a real strength for the organization but working without it can very quickly become a dangerous disadvantage: first risk can be the deconstruction of know-how, of collective, even the implementation of bad practices. Because even without being incompetent, trainers can generate results that escape initially until their return via undesirable event analysis.

5. Prospective conclusions

Proposing to conduct teams to work in simulated situation contributes to make work activities where practices are re-questioned, re-thought for a new individual and collective development. This point is fundamental for the management of industrial risky systems when research shows that management generally tends to migrate to areas of less secure operation than provided originally the designer. This type of migration, well described by De la Garza & Fadier (2007), can be induced, among others, by ignorance of some risks, constraints of exploitation and production, and a tolerance of the organization to accept exceeding certain limits (the normalization of deviation suggested by Vaughan, 1996 and 2005). Situation on simulator allows to re-examine the relevance of the terms of actions implemented by the actors in such a socio-technical system.

However, the operator faces a problem of investment, because the simulators, technical objects driven by calculator, are very expensive to purchase and to maintain. Technological developments are yet to reduce this cost and open new perspectives. Some developers have designed hybrid systems that combine the pilots' work environment (real size control panels) and virtual image (the panel do not have any actual button but is itself a large on-touch LCD screen that duplicates the buttons and configurable indicators by simple contact on the screen). In parallel the Serious Games are developed which immerses the trainee in a completely virtual world representing the most closely as possible the reality of exploitation, or, on the contrary, presenting a definitely decontextualized environment. The cost reduction is considerable because there remains only the calculator of the simulator, the technical object becoming obsolete. The question which must be asked is what is lost with such systems from the point of view of the integration of the know-how, because professional practice is not incorporated anymore in the same way (Fauquet-Alekhine, 2011c). This field remains to be explored.

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Training simulations: the complementarities of clinical approach and regulation approach

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Abstract

We aim to illustrate the provision of the analysis of activity according to the regulations approach, as a supplement to the clinical approach of working activity.
This illustration is accomplished on the piloting of nuclear reactors. The clinical material is acquired from simulated situations on full scale simulator of nuclear reactor, and from analyses of events of industrial exploitation.

The event analysis of nuclear power plant of Chinon puts in an obvious place specific characteristic for some events presenting a gap between realized work and expected task, including some cases presenting a specific typography. This characteristic results in the fact that the gap occurs because the control, although it is accomplished, does not allow to avoid this gap, due to an unsuitable object of control, or because it was not accomplished by the operator at good level: a kind of skip control phenomenon. Everything seems to take place as though the operator had wanted to control only a part of the activity, assuming that the whole activity would then be validated.

At first, the approach of the analysis of activity according to regulations (Faverges, 1972 ; Leplat, 2006) has been used. It allowed to break down, on cognitive plan, the basic mechanisms occurring during the realization of activity. We noted that in the case of activities based on the skill of the operator (see model of Rassmussen, 1994), he approaches activity by defining for himself one or several objectives and achieves them according to one or several final controls.

In term of regulation, we shall say that for control, the operator uses a comparative module to confront acquired results and expected ones. If comparison is satisfactory, task is ended. If it is not, the operator re-injects this result into the curl to make an analysis, to redefine objectives, then to compare the new acquired results and expected ones.

According to efficiency research, the operator implements secondary curls, with each their secondary objectives and their secondary comparative module.
But it can also bring problems : the analysis of working activities for nuclear safety events (Fauquet, 2004, 2006) shows that the operator can have tendency to validate task as a whole on the basis of a secondary comparative module, and not on the basis of the main comparative module. Everything takes place as though, in situation, he forgot the main objective of the task and focused only on secondary curls, which can be seen as subordinate cognitive regulations.

The analysis has led to suggest to training trainers and to work analysts to treat this problem by identifying the secondary objective and make the operators think about the reasons that led them to identify such an objective. This can be done through a collective analysis supported by the clinical analysis of working activity as developed by Fauquet (2006), notably by leaning on the capacity of the analyst to grab dialogic residues (Scheller, 2001) as a mean of feeding of professional controversy, and grabbing the agreed in speech for the re - question. This helps operators to understand the skip control phenomenon and to adjust their control for further activities.

1. Introduction

The aim of this study is to illustrate the provision of the analysis of activity according to the regulations approach, as a supplement to the clinical approach of work activity.

This illustration is accomplished on the piloting of nuclear reactors. Considering needs for the present study in terms of observations and debriefings, and taking into account the industrial constrains of work, the clinical material is acquired from simulated situations on full scale simulator of nuclear reactor, and from analyses of events of industrial exploitation. By operating event, it is necessary to understand a gap between realized work and expected task. Any gap detected leads to a treatment (Fauquet, 2004, 2006) and is assessed according to the International Nuclear Event Scale (INES). Quasi entirety is classified at level 0 (« no importance from the point of view of safety »). The treatment of gaps with weak

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stakes (minor events) allows to forestall the case of gaps with strong stakes (significant events).

The event analysis of nuclear power plant of Chinon puts in an obvious place specific characteristic for some events presenting a gap between realized work and expected task, including some cases presenting a specific typology. This characteristic results in the fact that the gap occurs because the control, although it is accomplished, does not allow to avoid this gap, due to an unsuitable object of control, or because it was not accomplished by the operator at good level: a kind of skip control phenomenon. Everything seems to take place as though the operator had wanted to control only a part of the activity, assuming that the whole activity would then be validated.

The simplest case is the following: the operator wants to start a pump. For it, he must turn and push a button.
The operator goes up to the button, turns it, pushes it, and makes sure finally that the button is definitely in the expected final position. He validates so the good execution of his task realization by checking the position of the button without proving that the pump is really crossed of the state « off » in the state « on ». This may seem amazing to read it on a paper but that settles as a reality in work situation, as work activity registers in a field of numerous and various constrains.
This simple situation finds analogies in various circumstances. For instance, the operator must put in a series of electrical cells to supply pumps. Inactive cells are pointed out by specific green tags, put down on each of them.
The operator, operating mode in hand, accomplishes this activity on cells through repetitive way, going from a row to another and from a group of rows to another one. It checks « connected cells » on his operating procedure; but in order to do that, he leans on recovered tags which he puts down on the floor in front of him. But for some of them, the connection is not real. However, according to the operator, activity is finally sold off and satisfactory since he has got all his tags.
As for the previous example, the operator validates an activity on a control which is not performed at good level; here, it is the recovered tags instead of the action on the cells.
On the basis of the well-known postulate of the psychodynamic offering that any behavior has obviously a sense (Dejours et al, 1994) and therefore that every person accomplishes a gesture or an action for a reason that is justified for himself, it appeared to us essential to try to understand the mechanisms which produce such results, to transform them, within the aim to reduce occurrence of events presenting this skip control characteristic.

2-Method

At first, we present the type of activities or tasks kept for the study; then we present how the approaches allow first an understanding of situation, then an analysis of this one with the aim of solutions elaboration.

The approach of the analysis of activity according to regulations (Faverges, 1972; Leplat, 2006) has been used. It allowed to break down, on cognitive plan, the basic mechanisms occurring during the realization of activity.

3. Analysis

We noted that in the case of activities based on the skill of the operator (see model of Rassmussen, 1994), s/he approaches activity by defining for her/himself one or several objectives and achieves them according to one or several final controls.

We envisaged a model, exposed thereafter and inspired by Leplat's work (2006), giving an account of clinical cases displayed above.

The objectives that the operator defines himself follow the analysis that s/he makes for the situation. These redefined objectives are elaborated through numerous parameters; for instance: constraints, tolerances, research of compromise between potential aims and various subjective motives. Motives call a subjective rationality here (Dejours et al., 1994) while the previous parameters are recovering from a cognitive-instrumental rationality. The first one is centered on task, the second on subject (the man at work). Subjective motives can be: support one's health, having good relations at job, ameliorating competences, optimizing workload, searching a promotion, for instance.
To assess the objectives defined by the task are reached, the operator accomplishes a control.

In term of regulation, we shall say that s/he uses a comparative module to confront acquired results and expected ones. If comparison is satisfactory, task is assessed ended. If it is not, the operator re-injects this result into the loop to make an analysis, to redefine objectives, then to compare the new acquired results and expected ones.
And, considering the subjective motives of which he is led to take into account, the operator implements secondary loops, with each their secondary objectives and their secondary comparative module. They allow the operator to be more efficient in action and to reduce the mental load linked to a given basic task according to the principle of cognitive economy (Allport, 1904; Kongovi et al., 2002).
These simplified cognitive regulations, increasing effectiveness, can also bring problems. It is precisely case in the clinical material recalled above.

The analysis of work activities for nuclear safety events (Fauquet, 2004, 2006) shows that the operator can have tendency to validate task as a whole on the basis of a secondary comparative module, and not on the basis of the main comparative module. Everything takes place as though, in situation, s/he forgot the main objective of the task and focused only on secondary loops, which can be seen as subordinate cognitive regulations.

The metaregulation (Leplat, 2006), the role of which is to regulate passage from the main regulation to a subordinate regulation (or secondary loop) to another, is summoned at the beginning of activity, but not at the end. So, task is sold off on an unsuitable comparison, since final main result is never compared with main objective.

For the operator, there is sliding of objective (from the principal to the secondary), sliding of loops of regulation without return (from the main to the subordinate), with focusing on this cognitive subordinate regulation to the detriment of the first one.

4. Treatment

After debate between analysts and simulator trainers further to the observation of several clinical cases as mentioned above, question settled of how to lead the trainees to understand, by themselves, mechanisms offered by this model.
Discreet steps are the following:

- in simulated situation, the trainers identify cases such as those named above for which control takes place only on the secondary objective (example: stopping of a pump and control only of the position of the button),
- in debriefing of simulation session, it is asked to the operators to tell the chronology of event,
- with the help of the trainers, the operators highlight the action relating to a secondary objective (example: turn and push the button),
- the trainers request to the operators to answer questions as such : "what made you turn the button?", to help the operator to come back to the main objective,
- trainers ask if final control has definitely been accomplished at good level related to the previous answers,
- then trainers explain simply the sliding of objective which took place, by saying that the operators accomplished a final control as though he had forgotten for which aim they performed this activity.

The operators are finally led to think what they could make on further situations to avoid this kind of problem.
At this step of discussion, the provision of the clinical analysis of working activity has all its gain. Because if the approach according to regulations is a remarkable mean to question the sequence of an activity in a rational way, it stops however to question on the basis of an explicative model.

Answers to questions must be then searched in opened up for possible discussion between actors of the situation of this question setting. It is there that the clinical analysis of activity intervenes as developed by Fauquet (2006), notably by leaning on the capacity of the analyst to grab dialogic residues (Scheller, 2001) as a mean of feeding of professional controversy, and grabbing the agreed in speech for the re-question.

The way of secondary objective to the main objective of activity is hired, then finished. On conceptual standpoint, the aim of trainers is to know how to bring the operators from the subordinate cognitive regulation back to the main regulation.

The trainers reactivate therefore during debriefing the metaregulation necessary for this transition, which did not take place in situation.

5. Conclusion

The electricity production by nuclear industry implements a system of detection and treatment of operating events in constant evolution: the aim is to ameliorate continuously exploitation and safety of installations.

For the treatment of events presenting specific characteristic, we have proposed an oriented debriefing analysis of the work activity.
Those events are polluted by skip control phenomenon due to an unsuitable object of control.

Using regulation approach, we have pointed out how the operators accomplish their activity through regulation loops, a main one with secondary ones (called subordinate cognitive regulations), each of them having their main (resp. secondary) objective, and their main (resp. secondary) result.
Moving from one loop to another proceeds of a metaregulation that does not operate at the end of the loops.

The analysis has led to suggest to trainers and to work analysts to deal with this problem by identifying the secondary objective and make the operators think about the reasons that led them to identify such an objective. This is done through a collective analysis supported by the clinical analysis of working activity. This helps operators to understand the skip control phenomenon and to adjust their control for further activities.

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Simulation training debriefing as a work activity analysis tool: the case of nuclear reactors pilots and civil aircraft pilots

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Abstract

Pilots of civil aircraft of Air France, as pilots of nuclear reactors of EDF, are training on full scale simulators. In both cases, training generally consists of briefing, work on simulator, and debriefing (Fauquet, 2007). Articulation and structure of these three stages introduce fundamental differences, partly given by the specificities of jobs.

Comparison puts in an obvious place a bigger nervous tiredness for the pilots of planes than for the pilots of reactors on simulator. This notably comes from the kinetics of tasks to be accomplished: in the cockpit of the plane, actions to be put in chains and the answers of the technical system are much quicker than in the control room of the reactor; on the plane, the scale of time is in the order of some seconds in some minutes, while for the reactor, it is counted in dozens minutes or even in hours.

Consequence is directly seen on the actors' decisions: the pilots of planes are led to put in chains decisions in a space of time which is counted in seconds, while the pilots of reactors have several dozens minutes in most cases. At the end of work on simulator (3h30 for the plane, 3h for the reactor), the pilots of planes seem exhausted and express it so: "we are emptied" (in French: "on est vidé"); pilots of reactor do not use such expression.
Then comes the debriefing after a 30 minutes pause. For the pilots of plane, debriefing lasts 1h30 against 3h for the pilots of reactor. Considering the state of the actors at the time of debriefing, we note that the pilots of reactors can be easily engaged in discussions about work practices in simulated situation, for at least two reasons: they are less tired, and verbal exchanges will be proceeded softly as there is more time for this.

Articulation of the two debriefings is therefore accomplished consequently. Approach is directive for the instructor of the pilots of plane when it is didactic for the instructor of the pilots of reactor (Béguin & Pastré, 2002) or analytical (Fauquet, 2007). Study points out that, if pilots' skills are not diminished by directive approach, there is a non-exploited potential which the comparison puts in an obvious place.

1.Introduction

As pointed out by many authors especially in medical training (see for example Northcott, 2002; Brackenreg, 2004), for a long time the focus in the scientific literature as in practice has tended to be on detailed descriptions of the action phase of the simulation training, forgetting how the reflective phase can be facilitated, especially through the debriefing. Our own experience shows that it is unfortunately still the case in numerous training centers disregarding the kind of professions. Yet debriefing appears to be of great importance for any work activity, non-simulated or simulated, which includes the learning process of simulation training. As written by Fanning et al. (2007), "although reflection after a learning experience might occur naturally, it is likely to be unsystematic." Rudolph et al. (2006) points out the importance of analyzing performances within a context of both trainers and trainees; people make then "sense of external stimuli through internal cognitive frames, internal images of external stimuli." Debriefing permits to discuss the non-action which is definitely a part of the real of the activity: "not doing anything, or perhaps better stated, continuing to sit or stand but not moving elsewhere, is itself an action" (Clancey, 2002). It must be understood that without any debriefing, the risk is to bound the simulation session to the realized of the activity which is different from the real of the activity. Non-actions are potential or possible actions not done but which might have been done, and are usually not observed.

Indeed, everyone who had the opportunity to observe such a debriefing will admit that the simulation training debriefing gives the opportunity to discuss together of what have been done by the collective and what has not been done individually and collectively. This is not possible without debriefing: in case of no debriefing, thinking the work proceeds of a reflection which is just

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individual. According to the clinical analysis of the work activity academic stream (Clot, 1999; Fauquet & Ceccaldi, 2004; Fauquet, 2006), in case of absence of debriefing, only the professional style reflecting the individual know-how and skills is concerned by the transformation process of training. But the professional genre, reflecting these professional aspects from a collective standpoint in terms of art of the trade, is not worked out. Thus, a part of the transformation / adaptation / integration of professional practices is not done if we consider that the collective or collaborative activity is as much important as the individual one.

Nevertheless, it appears that simulation training debriefings including these individual and collective reflection works about the work cannot always be done despite the trainers' will. This paper aims to expose the possible causes through the comparison of two training cases: i) civil aircraft pilots, and ii) nuclear reactor pilots.

2.Methods

In both cases, observations were done for simulated and non-simulated work situations, and interviews were conducted with trainers and trainees.

2.1.Civil aircraft pilots' training

Pilots of a French company have been observed during simulation training sessions and during short and long flights aboard an Airbus A320 and a Boeing B747-400 respectively. In addition, observations have been done during Crew Resource Management trainings which are classroom trainings gathering a bit more than ten pilots mainly to exchange about Human Factors items concerning their profession.

The simulators are full scale type, reproducing the real cockpit. Views through the cockpit windows are simulated by LCD screens and physical feelings inside the cockpit are reproduced by the mean of hydraulic motion. For example, air turbulence due to specific flight conditions can be felt by the pilots, as well as sensations concerning take off and land on.

The actors of the simulation training are the trainer and two pilots. The actors of the non-simulated situation are two pilots (within a team of 3 pilots for the long flight).

Simulation training sessions are made of several days distributed one by one over several month. It means that between two training sessions, there can be several weeks.

2.2.Nuclear reactor pilots' training

Pilots of the French company operating nuclear power plants have been observed in simulated and non-simulated work situations, and interviews were conducted with trainers and trainees. The teams observed were operating a 900 MWe water pressurized reactor type.

The simulator is full scale type, reproducing the real control room.

The actors of the simulation training are one or two trainers and a team of pilots which is usually composed of two operators, one chief-supervisor, a team manager, and sometimes a safety expert. The actors of the non-simulated situation are the team of pilots and co-workers according to the on-going work activities.

Simulation training sessions are made of several days distributed over several month but gathered in two or three consecutive days.

3.Results and discussion

3.1.The case of civil aircraft pilots

The simulation training session is composed of a briefing (more than 1h), 4h of simulation run with a mean time break of 15 minutes, and a debriefing of 1h30.

During the briefing, the trainer presents the scenario to be run during the training session. The briefing is mainly directive. Thus, most of the specific points are discussed even shortly before the simulator run. During the briefing, the trainer asks the pilots about the way they might deal with these points. This method could be surprising from the pedagogical standpoint and suggests questions concerning the learning process. But this aims to re-summon the know-how to be more efficient, and contributes to make possible a larger technical overview.

During the simulator run, the team has to maintain a high level of attention due to cumulative technical problems, and this in a continuous manner. In a cumulative technical problems context, pilots to make most of their decisions within a short time (from a few seconds to a few minutes). This is due to the fast kinetic of the flight parameters. After 2h, the time break is welcome. A team noticed: "after the 4h simulator run, we are emptied". Despite the work environment and the pilots' solicitations are less numerous than in non-simulated situations, they are yet permanent during the 4h run; in real flights, they are punctual. A trainer confirmed this feeling and explained that after these 4h, it becomes difficult to obtain active participation of the pilots during the debriefing. A pilot added: "the simulator runs are exhausting physically, mentally, psychologically. However, the length will change from 4 to 3 hours. Two hours […] would have been too short: we need to be warmed up; we need to know the co-worker [as most of the time, pilots meet them for the first time and will likely not meet him anymore]…; twice 1h30, it is good." After the simulation training session, "we are looking for a rest as soon as possible."

This is why the debriefing is also mainly directive. This last period of the training session consist a technical part (about 30 minutes) followed by chronological description of the simulator run (1h). The examined points are chosen by the trainer, and the chronological description is done by him too. Questions ask by the pilots are thus mostly concerning these points and the solutions are suggested most of the time by the trainer.

For example, the trainer says : “when you get the pack-off check-list, you say : ‘no I shall do it later’. No, do it now, you’ve got it under your eyes, it is not worth to keep work for later, because after you must come back to it, and you just go here and there.” The pilot acquiesces. Crew Resource Management trainings try to compensate these aspects by the reflexive work done within a 15 pilots group.

Despites all the constrains, trainers try to produce a real exchange between all the actors of the session: they try to make it a "interactive analysis" (Labrucherie, 2011). In this perspective, trainers are sensitive to make possible the expression of each. They also manage the time during which each will speak and sometimes suggest an order which will lead the most experienced or the one at the highest hierarchical position to speak after the others.

Furthermore, the debriefing is a special moment to deal with stress. For the profession, stress is an important parameter. According to the trainee’s level of stress, his performance can be either improved or deteriorated. Sometimes, it gives rise to surprising reactions whose trainees are even not aware (see similar findings in medical field: Geeraerts & Trabold, 2011). Trainees must be led to speak about the stress, while taking care to avoid a consecutive loss of self-confidence in them or their teammates. It is important especially to allow the trainees to identify the stress, to talk about it, and build with the trainer the conditions which will allow to lower stress levels towards acceptable conditions. The debriefing is the designated space for this, and the rationalization of the living situation which is allowed here helps the trainees to better manage it the next time and perhaps helps to develop a kind of meta-knowledge.

Providing such "interactive analysis" helps the trainees to gain access to a process of co-analysis that helps to put in discussion personal professional styles and sometimes the professional genre which is collective. It helps to develop the power to act. During this co-analysis called “cross-confrontation” (developed in section 3.2), the elements of discussion usually unnoticed in daily work life are maintained more clearly to allow their re-work. This is part of the role of the trainer in charge of the debriefing. In a Piagetist perspective, seeking to promote the taking of consciousness (Piaget, 1974), the trainer must make saying rather than expose which is not so easy to deal with taking into account all the constrains that make the debriefing mostly directive.

3.2.The case of nuclear reactor pilots

Several kinds of training sessions are available for the pilots (see description in Fauquet-Alekhine & Maridonneau, 2011; Fauquet-Alekhine, 2012). The training chosen here to be compared to the previous aircraft case is the so-called “situation involving” training; it is done on 3 days, each day broken down into a briefing, a run on the simulator, and a debriefing session in classroom. The briefing lasts less than 30 minutes. The run refers to the actual work activity on simulator (or simulated situation, with a time length of 2h30 to 3h). The debriefing session lasts 2h30. The existence of a time of integration between two sessions (from one day to another) is a real advantage from the learning standpoint: it is a time to think and learn unconsciously.

The briefing time placed just before the session on simulator helps anchoring of new practices thought during the debriefing of the previous day. This briefing is beneficial for all learning. The production of the previous session remains present in the minds of the trainees and is reactivated by the trainers at this particular time. This re-activates the attention of pilots on the items selected in the debriefing of the day before.

The run on simulator then lasts 2h30. It always begins with a transfer of information between the trainers and the operating team. This will contain a brief overview of the simulated installation state (current production level, eventually unavailable materials) and the work program provided for each simulated job (change in production to come, planned interventions, periodic testing). The term "short" is crucial, because it focuses on a first difference with the real operation situation: the 5-10 minutes thus with trainers are supposed to replace the minimum of 30 minutes devoted to an exchange with the shift team leaving the place and the one arriving, bringing together about fifteen persons concerned through a team briefing. At the outset, this first step contributes to that trainees do not forget they are on simulator and not in a real operating situation. Perhaps this is why very often, the trainees explain that they are "here to manage a failure which is to come." They therefore start by watch out the control room for the slightest clue in order to detect the earliest this hypothetical failure. Thus, we can sometimes observe trainees in simulated situation focusing on what seems to be such clue, for example, an indicator of level slightly more than normal.

In this simulation situation, the trainer’s place is not neutral. This place is both enveloping and inserted in the situation. It is enveloping through the distant observer position which will be essential in the managing of the debriefing.

It is enveloping because the trainer has full control of the scenario, by stabilizing or by adjusting the parameters of the simulator. The trainer also provides answers to reactor pilots based on the role s/he is led to play (only the head of the operating team is trained on simulator: for any hardware simulated intervention, pilots use the telephone to exchange with the maintenance technician, or a field worker for example, role played by the trainer): this is another form of adjustment of parameters of the scenario.

The place of the trainer is also inserted precisely because these contributions take place in the history of the temporal interval inside the simulated situation. The trainer may take the role of a field worker of the operating team, that of a maintenance worker, or voluntarily the disturbing role of any worker in the process.

Physical phenomena are rarely of fast kinetic: their variation usually takes several minutes, even for accidental situations during which specific procedures are applied, and during which the piloting team will involve 5 persons at a first stage, and a lot of supporting teams at a second stage.

After the simulator run, the team has half an hour time break. After that, they are ready for a several hour debriefing. This part of the training session is specifically hard if the session begins at 6:30 am: it means that the people will have to work until 01:00 pm. Usually, they bring some food and non alcohol drinks for the time break.

The debriefing, proceeding of a retrodiction (see Béguin & Pastré, 2002; Fauquet-Alekhine & Maridonneau, 2011) elaborates an analysis of what happened in a non linear way.

Based on the conceptual approach proposed by one of the French psychology theoretical streams, the clinical analysis of the work activity (Clot, 1999; Clot et al., 2002), we can highlight the importance of implementing the discussion of the workers' action by themselves (see Fauquet, 2006 and 2007; Fauquet-Alekhine, 2012). They are asked to explain what they are doing beyond of what is a priori agreed, to re-formulate – as in a more classical self-confrontation analysis (Theureau, 1992; Mollo & Falzon, 2004) – but also to understand the way in which each one is approaching the situation beyond what is agreed a priori and can remain implicit. The debriefing, seen in this framework, aims to extend the implementation discussion beyond the implicit within the story, suggesting that the development activity is governed by conflicts between concurrent activities that may be incurred for a same task to achieve but with different costs (Clot, 1999), which is a specific of the crossed self-confrontation practiced in the clinical activity. Must be put under discussion the carried out activity, but also suspended activities, thwarted or affected, and even including of counter-activities. In relying on the collective development of the story, the analysis highlights for the workers a lived and shared history of what has built the situation. During this phase of collective discussion, is implementing the "cross-confrontation" for a necessary comparison of the "personal styles" through the "professional genre" and make them to evolve. It is therefore a co-analyse in the collective debriefing which re-examine the professional genre. The shared rules of the professional genre are both constraints and resource for workers insofar as the rules are not fixed, but can be re-examined and processed. The professional genre performs a psychological function for each worker through a transpersonal dimension (Clot et al., 2002). This process is shaped by using the professional style of each, and by confronting each other within the professional genre, redefining it through the transpersonal memory (within the meaning of Bannon, 2000).

3.3.Comparative key points

From the ergonomic standpoint, one of the strengths of the configuration of the nuclear reactor simulator is that trainers are separated physically from the pilots, are sitting at a table big enough to receive control computers as notebooks. It is not the case of aircraft trainers who sit just behind the pilots. The physical separation allows an exchange of views in real time between trainers. Furthermore, it fosters an involvement of trainees in the situation and a dialogue between trainers without disruption or interference with the members of the team. Two other advantages for nuclear pilots concern the number of trainers (2 while 1 for aircraft team) and the continuous character of the training (2 or 3 days following while one punctually for aircraft team). The first advantage allows more relevant observations shared in real time and increases the debriefing quality, and the second helps anchoring of new practices thought during the debriefing of the previous day.

From the profession standpoint, comparison puts in an obvious place a bigger nervous tiredness for the pilots of planes than for the pilots of reactors on simulator. This notably comes from the kinetics of tasks to be accomplished: in the cockpit of the plane, actions to be put in chains and the answers of the technical system are much quicker than in the control room of the reactor; on the plane, the scale of time is in the order of some seconds in some minutes, while for the reactor, it is counted in dozens minutes or even in hours. Consequence is directly seen on the actors' decision making: the pilots of planes are led to put in chains decisions in a space of time which is counted in seconds, while the pilots of reactors have several dozen minutes in most cases. Furthermore, while aircraft pilots deal with problems within their bounded team (2 persons), the reactor pilots trespass this bound and have the benefit of supporting teams.

The debriefing for these two professions is therefore structured consequently. Approach is directive for the trainer of the aircraft pilots when it is didactic for the trainer of the reactor pilots (Béguin & Pastré, 2002) or analytical (Fauquet, 2007). Concerning the aforementioned debriefing quality due to the presence of two trainers for reactor teams, it must be noticed that what can be done for the reactor team is possible due to the possible time length of the debriefing. As the aircraft teams have directive debriefing, the benefit of two trainers is not so evident.

In addition, study points out that, if pilots' skills are not diminished by directive approach, there is nevertheless a non-exploited potential which the comparison puts in an obvious place. More recent observations have been done within the flight fighters training center of the French Air Force Army. Here, after about 1h flight simulator, the debriefing does not last more than 15 minutes, and it is not more than a feedback of the session from the trainer to the trainee. Both of them agree that after such training, the pilot is not mentally available to do more.

4.Conclusion

This comparative study has shown that the debriefing for a simulation training must take into account the main point concerning the physical and mental state of the trainees after the simulator run.

Although most of the studies show that a didactic approach gives better results than a directive debriefing, the first one being more efficient from a pedagogical standpoint, it is sometimes necessary to perform a directive debriefing because trainees' state does not permit the expectation of a participative exchange.

Nevertheless, even being involved in a directive debriefing, the civil aircraft trainers have shown that tending to the didactic approach could be possible, with less efficient effect than for the nuclear reactor trainers, but anyway actual. This gap may be compensated by other kinds of training sessions: it is the case for the aircraft pilots with the Crew Resource Management (a two days training session) during which pilots exchange about their professional practices. Following these studies, several changes have aoocured. Today (in 2012), simulator runs for aircraft pilots have been reduced to 3h30 which help training to be more efficient. A French fleet manager recently explained: "I realize how in terms of training we have made progress. In fact we work differently during training sessions. We have implemented the ATQP (Alternative Training and Qualification Program). It came from the fact that we realized that the most serious events occurred without technical failure, while we trained the pilots for major or minor malfunctions. There was a gap between what was taught and the 'real life'. We have inserted in our sessions exercises without failure (cases from our operating feedback), but which could generate organizational dysfunction within the crew, and thus could generate stress. The absence of procedure to manage the situation may be very dangerous if the crew is not robust or rather resilient. Feedback is very encouraging. Another innovation concerns the pilots' assessment: now it is done at the beginning of the training session. [..] We work about the weaknesses of each. As two sessions are undertaken by the same instructor, s/he can therefore adapt, in part, the sessions according to the pilots and and their weaknesses."

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Use of simulator training for the study of operational communication – the case of pilots of French nuclear reactors: reinforcement of reliability

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Abstract

Studies with French nuclear reactor operating teams have shown the established use of "standard of communication" which was efficient within the team but showed drawbacks when shared outside the team. A new standard has been implemented all over the nuclear fleet. Difficulties for implementation have been identified in terms of i) changing habits inscribed in mind and body of long date, ii) requirements of a new management approach concerning the work activity. Successful results have been obtained from the safety and production standpoints.

1-Introduction

Industrial processes involve workers in the development of specific communication due to their specific industrial context. The materials, the process itself, the sciences to which refers the process, lead them to name and then to use specific words to indicate what they want to do, where they need to go, what they expect from each other... With time and use, the words used are reduced by removing some syllables of some specific words. This induces in dialogues a lot of implicit. Most of the time, it helps workers to be more efficient, because exchanges are done faster, mental resources are used to other cognitive tasks than making and understanding long sentences. But sometimes, it could produce some safety events that are undesirable. The aim of this paper is to present a study concerning the balance between operational communication efficiency when words are reduced, and potential safety event occurrence. It then presents the way habits can be changed on this field and the difficulties this change implies.

This illustration is accomplished on the piloting of nuclear reactors. The clinical material is acquired from simulated situations on full scale simulator of nuclear reactor, and from analyses of events of industrial operating. By operating event, it is necessary to understand a gap between realized work and expected task. Any gap detected leads to a treatment (Fauquet, 2004, 2007, 2008a) and is assessed according to the INES scale. Quasi entirety is classified at level 0 ("no importance from the point of view of safety").

2- Progressing of the "observation-analysis" period

For some reasons too long to expose in this short paper, we focused our observation efforts and analysis on the activities of the men at work in control room.

The actors have been seen in 2004 and 2005 in control room of real operating situations, and in control room of full scale simulator (Fauquet, 2009). This represents about fifty hours of observation. For this experimentation, specific scenarios were developed and being used on simulator to put the actors in potentially difficult situations of communication. The aim was to understand and to assess the robustness of the communication modalities. For not simulated situations, observations were made over the working periods of day rather than night, during periods often implicating numerous exchanges between persons (the frequency of night exchanges is much weaker).

A synthesis of observations and analysis were then presented and opened up for discussion in teams (Fauquet, 2006). These results were inserted into the study in progress at the national level of the firm to contribute to the elaboration of standards of communication. We discuss it in section "change of communication practices".

3-Effectiveness and limits of operational communication: observations - analysis 2004-2005

Observations show that the mode of fiabilisation of the exchange of information is function of the complicacy of activity and working context. The more situation is complex, and the more the actors feel the need to explain their understanding of activity, and to question the interlocutor. This was modeled par Rasmussen et al. in 1994.

This mode of reliability, by the explicit enunciation of what is done and will be done, is particularly implemented when the actors are not much familiarized with the task to be accomplished.

In simpler contexts (that is to say for work activities known by the actors because already done several times), observations realized in 2004 and 2005 showed that

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* This work has been presented at the *Int. Conf. on Simulation Technology for Power Plants*, San Diego, USA, Feb. 21-26, 2010.

recurrent reliability modes were in general to the number of two:

- Reliability of oral exchange by the written support: the oral message is enforced by leaning on the visual support which is the operating document, held in the hand by one of the interlocutors so that the others can support their understanding of the message by reading at the same time.
- Reliability of the oral exchange by the material support: the oral message is enforced by leaning on the visual support which is the control panels of the control room, by indicating of a gesture the control organs concerned by the message, which are affected by a tag indicating the name of equipment. However, this assumes that each of the actors understands that this concerns what about they speak.

Observations also confirmed (because known well in advance) that the mode of oral exchange used a "standard usage of communication" due to this industrial environment and founded on the typical location of equipments in the industrial places.

This is made possible due to tasks to be fulfilled and due to the location facilities of equipments in the industrial places. In effect, most of tasks concern group of given equipments identified as belonging to a «basic system" of the industrial process.

Every basic system is spotted by a number and a trigramme (example: 1RRI, 2RCV, 4SEF) where the number designs the reactor to which is devoted the basic system.

And every organ is spotted by three numbers and two letters; both letters indicate the type of organ (example: PO for pump, VA for valve) and number designs the number of the organ. So, 1RRI002VA indicates the valve number 2 of the system RRI of the reactor number 1.

This functional mark "1RRI002VA" is replaced by "2VA" [two-vee-ay] in what we named the "standard usage of communication". As we explained it, most of part the tasks concern group of given equipments identified as belonging to a "basic system".

In these conditions, the exchange between actors concerns a specific basic system and speech starts in general with the precision of the trigramme of the basic system, to evacuate it then besides of speech to make more efficient transmission and understanding of information.

In effect, the transmission of information searches systematically to minimize the number of words and the length of the signifier, what passes systematically by evacuation of number of reactor and the trigramme of the basic system.

After the first enunciation of number of reactor and the basic system, these are then put down as implicit.

Example = the pilot of reactor number 1 is meeting a problem for which he sends a field worker to control the equipment:

> "Reactor 1, I have one worries on the system RIS. In the pushing back of the one-pee-ow. I would like that you go to see in place if the fifty-nine vee-pee is opened correctly."

It is necessary to understand here that the pilot asks for a control of the position opened for the valve 1RIS059VP located downstream from the pomp 1RIS001PO. Complete formulation would give:

> "Reactor 1, I have one worries on the system RIS, in the pushing back of the pomp one-RIS-zero-zero-one-pee-ow. I would like that you go to see in place if the valve one-RIS-zero-fifty-nine-vee-pee is opened correctly."

Other specific case: observation and event analysis put in an obvious place one generality. Some workers weaken the quality of exchanges because their activities allow them only exchanges by telephone, and the actors have then tendency to implement an implicit communication by habit (Fauquet-Alekhine, 2009; Fauquet-Alekhine & Pehuet, 2011) and to neglect the reformulation of request while it takes all its importance in such context.

Cases of partial reformulation of exchanges of messages were noticed during this specific context ; in these cases, the actors choose the key elements in the message in order to make more reliable according to themselves the understanding of asked action, such as a part of functional marks, of number of place, of number of task form. It is still a product of the standard usage of communication displayed above.

4-Safety event analysis

We explained how the actors implemented a "standard usage of communication" founded on the functional location of equipments and on a specific protocol of exchange inserting implicit information, notably by the reduction of the signifiers. At first glance, the implicit in teams appears as a strength as much as it helps to have more efficient collaboration, notably via the exchange of information, by allowing a quicker understanding of information.

But this implicit functioning is specific to a given group by using a code which is its own one; if the constitution of the group changes, it is necessary to make hypothesis that the implicit will not work anymore so efficiently, since one or several persons of the exogroupe have no full knowledge of the group code.

The event analysis has shown which can be consequences.

If the "standard usage of communication" can lead to critical situations, then it is clear that it is necessary to replace it with another standard without loosing its efficient side or loosing few.

5-Changes of communication practices

Studies led on the nuclear plant of Chinon were compared with other studies led on other nuclear sites in France. Results introduced above were confirmed by the analysis of observations accomplished as well as by the event analysis (Fauquet, 2006; Fauquet-Alekhine, 2009).

In 2006, the head quarter of the company decided to hire a Human Performance Programme on all the 19 nuclear sites of France. This program comes from studies made in numerous industries, in France and abroad, and has been fostered by studies such as that introduced here, and others (Colas, 2001; Rousseau, 2008).

The Human Performance Programme urges the actors of the nuclear plants to make more reliable their interventions by using 6 reliability practices. We shall be focused on one of the practices of expected reliability concerning exchange between actors during their working activity. It is named "reassured communication". The prescribed usage of communication has vocation to take the place notably of the "standard usage of communication" presented above, and to hire those who do not use standard of communication to apply it.

It is expected for interventions on equipments of the nuclear installation, particularly during routine activities. It is said "3 ways": interlocutor INT1 enunciates a request, interlocutor INT2 repeats request, and interlocutor INT1 confirms or rectifies.

6-Changes of communication practices

Going to this mode of "reassured communication" cannot be immediate, all the less that the modalities of communication in work, such as the "standard usage of communication" exposed above, are inscribed in mind and in body of long date (see for example Fauquet, 2008b ou Dejours et al.,1994). We explained that the way the actors communicated between them has a sense which we tried to understand. Thus, any request of application of another protocol of communication is going to be confronted with established practices. In effect, this habitus is historically and socially constructed according to rigid norms. Changing these attitudes is all the less easy as the sense of behaviors is still not aware for the actors. This is valid for reassured communication, but also for other reliability practices inscribed in the Human Performance Program.

To lead the actors to implement and to insert into their professional practices this modality of reliability, several stages were worked out since 2007.

These steps are carried out by management at all hierarchic levels, helped by human factor consultants or by specialized training people. We shall not develop the detail of these steps because it is not the main object of this publication.

The first step was a pedagogic training of preliminary.

The second step was principally a step of analysis.

The third step is a stage of permanent deployment.

This third step also leans on the full scale simulators, maintenance simulator or piloting simulator. They are used to teach the workers and the managers the technical gestures of reliability practices, and to help them to incorporate these practices, that is to say to live them with the body in working situation. Simulated situations also make demonstration of the effectiveness of reliability practices at work (see Klein et al., 2005; Fauquet, 2008c; Fauquet-Alekhine, 2009).

In parallel to these centered training situations on simulator, the managers offer punctually in the teams pedagogical animations, the objective of which is to support in the mind of the workers the practices gain. Management create this type of debate regularly in teams.

For it, management is also subjected to a specific training. A computer tool to draw identification and the treatment of these difficulties has been developed. To make more dynamic deployment beyond the action of management, role models workers are identified and trained specifically. They are persons acknowledged technically by the colleagues, who were spotted to have very quickly accepted reliability practices. These role models are able of helping or recommending their colleagues on the subject. The role models are enlivened in local network, what allows them to share their experience and knowledge, difficulties and solutions.

7-Conclusion

The French nuclear production division of EDF has decided to involve every worker in a large reliability activity plan, the Human Performance Programme, in which reliability of operational communication is concerned.

We shall take two examples to objectify results acquired at national level:

- The number of reactor automatic scrams of diminished by a factor close to 2 between 2007 and 2008, and the decrease is going on in 2009.
- The number of events which would be owed to non-application or ineffectual application of reliability practices diminished by a third.

These results are particularly satisfactory as for the effectiveness of progress. Yet, it also objectifies the remaining margin of progress.

However, changing from a mode of "standard usage of communication", inscribed in mind and in longstanding body, to a mode of "reassured communication" prescribed, cannot be immediate and will never be absolute.

Two questions at least now can be put in study with a view to following ongoing progress:

- Since the mode of communication between workers is led to change, evaluating from a tradition to a prescription, how this mode of "reassured communication" prescribed can generate "misappropriations" of application? In effect, numerous studies, among which notably those of Clot (1995, 1999, 2000, 2002, 2003, 2004), put in an obvious place the involvements of prescription on working activity and what can implement the actors to answer it in a deviated way or not.
- How the future generations of workers will put in their professional practices this mode of "reassured communication" prescribed?

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Simulation training to prepare for robotic intervention in a hostile environment

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Abstract

There are work activities for which the action of intervener directly on the object of work is impossible, most of the time due to safety constraints. It is the case for example of a polluted industrial environment or, quite differently, the human body. In the first case, interveners may need to keep far from the restricted area due to chemical hazards or high radioactivity for example. The second case may be surgeons preferring to be as less invasive as possible in order to reduce anatomical damages; the aim is to help patients to recover health as fast as possible. Some cases allow a training in the real context and for others, the risk factor is important enough to imply training in simulated situation. This may be done on full scale or virtual simulator.

Comparing pilots of robotic devices for radioactive hostile environment at INTRA group on one hand, and physicians for mini-invasive surgery at IRCAD on the other hand, we points out the constraints of each profession and the consequences on the associated simulation training, with a focus on the first profession (to make it simple, we suggest to consider a work situation as a "simulation training" as soon as it is a training session AND a part of the situation at least is simulated, such as physical phenomena or environment for example). This was done on the basis of interviews of managers, trainers and trainees, and with the help of observations done in real and simulated situations.

Our findings show how the "hostile" character of the work for robotic device pilots of INTRA sizes the work activity while surgeons are mainly led and bounded in their work by the aim to keep the patient's life. The "hostile" character of the work induces a high probability of unpredictable facts and the consecutive risk of destruction of the robotic device which would make the mission fail. In terms of training, this means that the simulated activity is most of the time far from the real situation and thus makes the transference process of knowledge and know-how from simulation training to non-simulated activity more uncertain than for the mini-invasive surgery. INTRA group copes with this difficulty by training the pilots in a large diversity of cases on full scale simulation training, and through virtual simulation training using ITUCR[1] software. To go farther, the use of such a virtual simulator in order to offer to the pilot a lot of different possibilities of environments would be a real benefit.

1. Introduction

High risk work activities imply sometimes risks for the interveners (endorisk producer), for the people concerned directly or indirectly by the activity but not interveners (exorisk producer), sometimes for both. Astronauts for example are most of the times in the first category. Surgeons or anesthetists are mainly in the second category. Civil aircraft pilots are of the third category with risks concerning both themselves and people travelling in their plane.

For some professions and in some cases, specific constraints imply not to intervene directly in contact with the object of work activity.

Endorisk producing activities are the case of people operating in hostile environment. For example, deminers use robotic devices to approach the bomb susceptible to explode while they try to deactivate it. The same for operators involved in post nuclear accident who must check radioactive industrial equipment: we shall here be concerned by the group INTRA which has developed specific robots for this purpose (Fig. 1). INTRA has to conceive, to operate and to maintain a fleet of robotics machines 24 hours / 24 hours capable of intervening, in the place of human beings, in a major nuclear accident, in and around the industrial buildings of its members. It also assures the continuous training of pilots within the installations of companies members: EDF, CEA and AREVA. (web site: http://www.groupe-intra.com)

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http://www.groupe-intra.com

[1] ITUCR : Russian Agency of Nuclear Energy - Center of robotics (Moscow, Russia).

Fig. 1. Examples of INTRA robots driven in a simulated hostile environment with the control panel (middle).

For exorisk producing activities, the case of surgeons is interesting. They are involved to seek the least invasive intervention possible for the patient. To achieve this, mini-invasive surgery appears to be an appropriate solution as it is the least invasive manner of operating. Instead of opening up the body with large cuts and move the organs, small holes are done to insert surgical tools and camera for a very local operation. Since several years, IRCAD (Research Institute against Digestive Cancer, Strasbourg, France) has developed such a technology for the digestive apparatus based on the use of robotic devices (web site: www.ircad.fr). Among IRCAD digestive cancer research laboratories, there are a research and development department in computer sciences and robotics, and a training center in minimally invasive surgery (see for example Soler & Marescaux, 2011). In this frame, IRCAD welcomes surgeons in training sessions to develop the use of robotic systems (Fig. 2) such as those developed by Intuitive Surgery (web site: www.intuitivesurgical.com).

Fig. 2. The Da Vinci surgery facilities and the surgeon on the right engaged in the control unit.

In both aforementioned cases, interveners use robotic devices, or robots. Some cases allow a training in the real context and for others, the risk factor is important enough to imply simulation training. To make it simple, we suggest to consider a work situation as a "simulation training" as soon as it is a training session AND a part of the situation at least is simulated, such as physical phenomena or environment for example. This may be done on full scale or virtual simulator using part or full the robotic devices. A robot is here a tool that prolonged the intervener's body for him to act on the work activity object without direct contact. According to the Macmillan dictionary, "robot" is a machine that can do work by itself, often work that Humans do. We must had here the remote control character of the robot as the machine does by itself what Humans ask it to do.

Yet, if this definition may fit both of the aforementioned cases, the robot in each case is quite different. They are designed according to the work aim, to the environment, and to other constraints inherent to the profession specificities. As a matter of fact, the way the robots are piloted and the training associated are different.

The present study aims to analysis these differences and what are the consequences in terms of training design. The problematic is interesting because, at a macro level, both INTRA and IRCAD work activities can be described in a same manner: an operator intervenes within a risky framework in an environment where safety constraints lead to use a robotic device. In both cases, the interveners work inside the object of the work activity: the hostile environment for INTRA and the patient for IRCAD. But when we watch the details, they become quite different. INTRA is mainly led to keep on working the robot within a hostile environment: the loss of robot brings the mission to an end or implies a delay and the hostile character of the environment may contribute to the loss of the robot. IRCAD is mainly led to keep the patient alive with less damage as possible. If the robotic device fails (is found not suitable or does not work), then the surgeons can come back to the classic invasive technique and achieve the mission. This is not possible for INTRA since anyway the mission will be performed by a robot. Furthermore, the "hostile" character includes a priori the unknown dimension of the environment: while the human body is usually known for surgeons of IRCAD, the hostile environment contains a part of unknown configurations because hostile environments are most of the time hostile due to destruction. Comparing both professions and the associated training, we aim to identify what is done by each one and appears to be of great importance for one and not for the other. This will help to emphasize what appears as key points of the work activity in terms of pilot's skills and the comparative study will highlight why these are keys points. This will help the trainers to enforce some specific points and will help other professions or even newly concerned professions to conceive an adapted training according to their kind of robotized work activities.

2-Materials and method

For both work activities, interviews have been done with managers, trainees, trainers and observations have been carried out on simulation sessions only.

Trainees met are not novices: they are experienced professionals, who are trained to new technical specificities, new procedures, or just re-trained to maintain their skills.

For both professions, two kinds of situation have been seen:

- Simulation with virtual representation of the object of the work activity, which implies computer graphic conception.
- Simulation with a real representation of the object of the work activity: an experimental hall where move robots for INTRA, and an anesthetized pig for IRCAD.

Of course, for the first kind of situations, the whole simulator take a reduce form. And for the second, the case of INTRA presents a particularity: despite the simulated character of the simulation session, the loss of a robot (if happens) will be real: a robot falling from the stairs is really damaged and the waste of money may be up to 1Meuros.

Figures 4a & b show INTRA robot on full scale simulation and control panel. Figure 4c shows the virtual simulator for INTRA: the video images on the control screens used by the pilot are virtual while provided by cameras fixed on the robot in full scale simulator. Generated by the calculation software Robsim developed by ITUCR (Volov et al., 2002), they can reproduce any environment according to the programmer's desire. The trainee is thus sat in front of the real control panels, and all that concerns the robot and cables are absent.

Fig. 4 a) INTRA robot on full scale simulation session, b) INTRA contro panel during training session, c) The virtual simulator for INTRA with virtual images on the control screens generated by the calculation software developed by ITUCR.

Furthermore, for pedagogical purpose, ITUCR software provides additional views of the robot moving in the hostile environment (Fig. 5 a & b). This allows the trainer to have other arguments whilst explaining what is going on and helps the trainee to improve the feelings of what was done, making a relationship between what was viewed on screens and what can be seen from far.

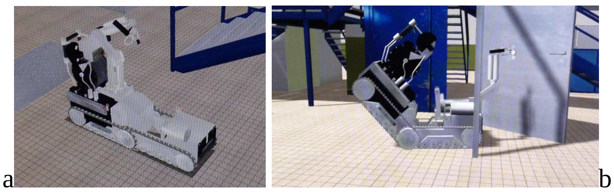

Fig. 5 a & b: Additional Robsim (ITUCR) views of the INTRA robot moving in hostile environment.

Figures 6a & b show the virtual simulator used in IRCAD: the video images on the control screens used by the pilot are virtual. Generated by the software developed by Intuitive Surgery, they reproduce the inside human body environment according to the anatomic laws. The trainee is thus sat in the real control panels, and all that concern the robotic device and cables are absent.

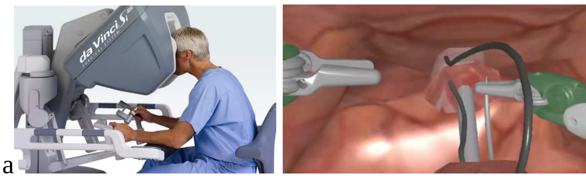

Fig. 6. The virtual simulator Da Vinci used in IRCAD and developed by Intuitive Surgery and a virtual simulation through Mimic software on 6b.

We shall consider trainees who know the job and who do not train on simulator for an initial training to learn the work activity as beginners. This choice is made in order to have comparable cases. This is necessary because while all INTRA pilots are concerned by an initial training on simulators, it is not the case of surgeons at IRCAD: they first learn their profession, practice, and then are concerned by the use of a robotic device.

For surgeons, observations have been done on simulation training sessions performed in IRCAD (Institute for research against cancer of the digestive apparatus, Strasbourg, France). We call here "simulation session" the training of surgery teams in the theatre where the human patient has been replaced by a pig (chosen for its close anatomical and physiological characteristics to human). The training session involved two surgery teams for mini-invasive digestive surgery, working on DA Vinci robot from the Intuitive Surgical company, currently the most used surgical robot worldwide. In this context, the surgeon works in specific conditions (see Fig. 2): the physician is sat in front of a control device (right hand side of the picture), the head is put on to the video box where he has a stereoscopic vision of the operative scene filmed by two cameras, his arms are sustained by a support for the hands to be involved in the manipulation of two rings per hand. Through these rings, the surgeon manipulates instruments introduced inside the patient's body and realizes the surgical operation.
Similar observations have been done with during simulation with virtual representation of the object of the work activity.

3-Results

The main result is interesting by the way it structures relationship between the work activity and the variales [organization, tools]. It claims that the object of the work activity is sizing most of the parameters and factors of the intervention because this object determines the endorisk or exorisk character or the activity. In fact, it is the classical finding that the work activity is organized to minimize the risks, taking of course into account cost and production objectives (Fig. 7). Other constraints may be added such as legal or technical constraints.

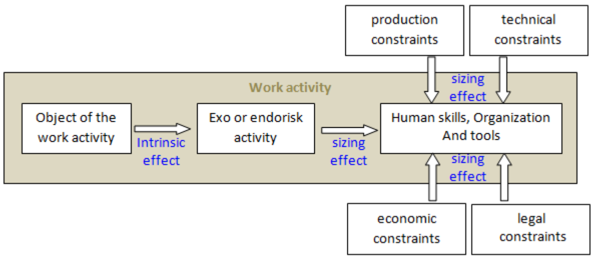

Fig. 7. The influence of the object of work activity in sizing organization and tools through the exo/endorisk characteristic.

In both cases (INTRA pilots and IRCAD surgeons), organization and tools contribute to minimize risks but produce nevertheless side-effect risks.
For example, INTRA pilots explain that the hostile character of the environment where they must intervene implies the robot device to be able to go far from them where no human being is expected to go (at least at the time they are called to be in the place). As the hostile environment is usually a damaged industrial plant (case of Fukushima nuclear accident in 2011 for example), a radio remote control is not possible as said above: the industrial plant are full of metal which interfere with radio waves, and nuclear plant have so thick walls that waves are stopped. Thus the robot unwinds cables whilst progressing in the environment which is usually damaged. The fact that the 350 meter-cable could be trapped somewhere and block the robot on the way back or damaged by anything falling down is what we call a side-effect risk. We could name it a consecutive risk.
At IRCAD, the mini robotic device is used to reduce pain and injuries of the patient. The robotic device does not progress within a large space: robotic tools are inside the patient's body, and their movements will be bounded within the space of the surgical intervention. Thus, the presence of cables or other robotic links is dealt with: everything is put in the right place at the beginning of the operation and then nothing is expected to move. If the surgeon loses the string used to sew the cut flesh, it may be difficult for him to recover it with the mini-invasive robotic device. After that, making a knot to stop the string is another difficulty for which he has to be trained in order to not injure the patient whilst handling the string. These are other examples of side-effect risks or consecutive risks. Nevertheless, the surgeon is close to the patient. S/He keeps in mind that any classical surgery remains available.
As we see, at INTRA, the intervener must care about the environment in the aim the keep safe the robot which will achieve the mission. At IRCAD, the surgeon must care about the environment in the aim to preserve it.
We shall discuss below the consequences in terms of stress for the intervener.

In both cases of robot piloting (INTRA pilots and IRCAD surgeons), interveners are concerned by:

- the same problem of piloting operation: movements are done according to cameras,
- minimizing risks implies simulation training,
- simulation facilities are partly based on virtual simulation and partly based on full scale simulation.

But an important difference concern the social support: while the INTRA pilot works with a co-pilot and a chief supervisor who can ask at any time the advice of colleagues who may help him concerning the choice to be done, on the contrary the surgeon is alone. In addition, most of the time, the surgeon's choice must be done at once, while the INTRA pilot has a minutes, sometimes hours to choose. It makes a huge difference in terms of decision making process.

4-Discussion

The sizing effect due to its exo or endorisk character has a direct influence on the intervener's state of stress. This appears clearly after observations and especially after interviews. Table I shows what we explain here after.

INTRA pilots explain that getting the robot to move forward is difficult: an obstacle or an unstable surface might knock over the robot or block the cable. In such configuration, the robot is immobilized and no other robot may be sent. Anyway, the best solution remains the one which will not involve human being in a local intervention. As a consequence, the pilot must do what is best to keep the robot operational and mobile. S/He cares about the objective of the mission and about the "life" of the robot. S/He keeps in mind that any mistake will abort the mission. "No more robot, no more mission" for the pilot. After such an issue, other people will take charge of the problem and have to enter the area while her/his objective is to avoid exactly that.
In the case of INTRA pilot, reaching the goal of the work activity is directly linked to the robot.

IRCAD surgeons explain that the main objective is to reduce pain and injuries of the patient. The robotic device is used in this aim, but any failure using this technique does not keep away from the possibility to come back to the classical surgery, a relatively easy shift as the patient is close to the surgeon with all the facilities available to do so. The "No more robot, no more mission" for the surgeon does not apply here.
In the case of IRCAD surgeons, reaching the goal of the work activity is not directly linked to the robotic device since the surgeon can change from the mini-invasive technique to the classical surgery.

From the psychological standpoint, the "No more robot, no more mission" implies consequences on the intervener's self-esteem. A mission success is more probable for the surgeon, or should we write a mission failure has a higher probability to occur for the INTRA pilot. As the pilot knows it, it is important for him/her to be self-confident enough in order to have a good but yet realistic self-perception of his/her skills and competence. This self-perception is directly link with the self-esteem as it contributes to foster it (see for example: Sainsaulieu, 1997; Lieury & Feunouillet, 1996).

Table I. Implications of the risk characteristic on the mission issue: each line induces the following.

	INTRA robot pilots	**IRCAD surgeons**
Risk characteristic	*Endorisk: hostile character of the environment*	*Exorisk: Reduce pain and injuries of patient*
Tool sizing	*Robotic device going far from the intervener*	*Mini robotic device close to the intervener*
One potential consequence	*If robot is lost, no human will go to deal with or do the job, or if so, with high health risks*	*In case of robot failure, human (surgeon, usually the intervener themself) will go to deal with or do the job*
Effect on the intervener	*A mistake may lose the robot and stop the intervener's contribution*	*A mistake may lose the patient, but if any robot failure, the intervener will cope with classic surgery*
Link robot-mission issue	*No more robot => no more mission*	*No more robot => alternative: classical surgery*

In this context, the virtual simulation is a necessity both from economic as from pedagogical standpoint. Both situations are high risk socio-technical system as defines elsewhere (De la Garza & Fadier, 2007; Fauquet-Alekhine, 2012a). As for any of such systems, INTRA robot pilots and IRCAD surgeons take advantage of virtual simulations because it avoids damaging robots or pigs resp. (which cost money and animal lives) and permits a broader diversity of training cases with a possibility of replay or a possibility to see what cannot be seen if not virtually simulated. This is well illustrated by the Robsim additional views on Fig. 5 which cannot be so easily available on full scale simulator.

As shown is previous works (Fauquet-Alekhine et al., 2011 & 2012), simulation training is expected to reduce the interveners' stress level. We showed how this reducing process could help the subject to work in the appropriate Human Functional States (Leonova, 2009; Fauquet-Alekhine, 2012b) with regards to the Yerkes & Dodson theory concerning performance versus stress (Yerkes & Dodson, 1908).
The variables potentially inducing stress are similar for a few of them and different or opposed for others. Table II exposes a list of the main variables producing increase of intervener's stress.

Simulation training appears then as an appropriate solution to reduce these stressful exogenous parameters (meaning that these parameters are due to external sources as defined by Fauquet-Alekhine, 2012b).
Especially virtual simulation gives the opportunity to build an environment as close as possible to the expected one. Even in case of damaged industrial plant, assumptions done about damages may help to elaborate the most probable environment for improving the intervener's knowledge which is possible with Robsim developed by ITUCR: computer simulator can be used to evaluate the feasibility of some operations; for example, by the virtual model of environment where accident happened can be checked the route for the robot and feasibility of technological operations. The same for surgeons in case of tumor: it can be added to the known anatomical environment the induced special disturbance within the virtual simulation. The surgeon is thus trained as closely as possible to the reality.

Table II. Main variables concerning intervener's stress.

<table>
<tr><th></th><th>INTRA robot pilots</th><th>IRCAD surgeons</th></tr>
<tr><td>Shared stressful parameters</td><td colspan="2">o time pressure
o cost pressure
o safety / physical risks for others
o physical discomfort due to the premises or position or noise or ambient temperature</td></tr>
<tr><td>Different stressful parameters</td><td>• Risk of destruction of material by falling in holes or buildings falling
• unknown environment => self-perception of skills & competence
• unknown environment => high probability of unpredicable facts => self-perception of skills & competence
• the weakness of the simulation training, not so close to non-simulated situation
• a disturbed (not flat) environment source of obstacles which could block the robot; thus, a significant probability to lose the robot
• possible loss of metrology, especially video
• noisy, bad visibility environment
• a unusual practice : the real situation happens very few times (*)</td><td>• Risk of patient death
• Partly unknown environment
• Alone for decision making
• Very fast kinetic of phenomena
• sometimes difficulties to watch with time if glasses needed (effect of sudation and tiredness)</td></tr>
</table>

(*) *Since its creation, INTRA was never asked for an emergency in nuclear hostile environment due to an industrial accident. The few interventions concerned maintenance problems and where operated in order to reduce or avoid the radioactive exposure of workers.*

Thus, virtual simulation training reduces the intervener's lack of knowledge concerning the environment. By reducing the stressful intensity of this variable, the fear to lose the robot (INTRA) or to injure the patient (IRCAD) is reduced. It means that we obtain a consecutive decrease of another stressful variable. Thus, the intervener's internal resource becomes available to manage the other stressful variables and we obtain a global improvement of the intervener's Human functional State.

5-Conclusion

The present study has emphasized what are key points of the work activity in terms of pilot's skills and the comparative study has helped to highlight why these are keys points.

This might help the trainers to enforce some specific points and help other professions or some recently implicated by this problem to conceive an adapted training according to their kind of robotized work activities.

Additional interviews are planned to investigate the effect of the distance between the control facilities and the robotic devices: for example, do two meters give the same stress to the surgeon than 2000 km in case of tele-operating?

Acknowledgment

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Using audio-video recording on simulator training sessions: advantages, drawbacks, and dangers

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Abstract

Simulator training sessions for teams and crews concerned with high risks systems are definitely up-to-date. For some big companies (refineries, chemical or nuclear plants) or big organizations (hospitals, universities), full scale simulators concern initial training as reinforcement. It involves countries in all parts of the world. One of the tools which can be very useful for the trainers working on such simulators is the audio-video system. This paper explains why, and gives advice in order to use such a system in good conditions. This advice is based on many observations and exchanges done with aircraft pilots, anesthetists and surgeons, navy officers, and nuclear reactor pilots.

1- Introduction

Simulators are now commonly used to train the teams involved in the process concerned by high risk work activities. Nuclear or chemical plants, for example, require to be managed from complex control room by a staff of operators who must make as less as possible mistakes: some of them, or several combined together, can yield to dangerous situations for the people working on the plant, or the ones living outside the plants. Another example is the aircraft pilots who must control their plane in order to keep all the crew and passengers alive. The same for the physicians (surgeons or anesthetists) who must have the appropriate behavior to keep or save the life of patients.

To train all these people, many companies or organizations have invested in full scale or part task simulators: people can thus be trained in difficult situations without any danger for anybody. One of the tools which can be useful for the trainers on such facilities is the audio-video recording. But some do not purchase it because they do not find this useful, or do not have the money to buy the facilities, or do not know what must be chosen.

We provide here advice in order to show the utility of such systems, and to help trainers to use them in good conditions.

2- Context and purpose of the use of video during simulator sessions

When pilots or operators are trained on full scale simulator, usually, a debriefing session takes place for them to discuss together with colleagues and with trainers about the work done during the simulated situation (Fauquet-Alekhine & Pehuet, 2011). This debriefing is important and we have already discussed its utility (Fauquet, 2006; Fauquet-Alekhine, 2012a): it is the time during which individual and collective work activities are put under discussion, within the group of workers. This makes then possible for the workers to transform or not their individual and collective practices, to decide together this evolution, in order to share the rules of their trade. It is a time to understand together what has gone right or wrong, and then be conscious of good practices, or find solutions to change inappropriate practices.

Usually, the analysis produced by the trained team and the trainers is based on what everyone of them is able to put together in the collective discussion. Most of the time, this narrative, which can be called "retrodiction", is enough for the people to discuss together about the work effectively done or not, and to point out most of the positive or negative characteristics of the collective or individual work activities.

But all trainers know that, sometimes, it could be comfortable to have a kind of "proof" of what has happened during the simulated situation, because i) sometimes, trainees are not so convinced of what is reported about what they did or about what happened by colleagues or by trainers, or ii) people do not understand the way they effectively did what is reported. In such a situation, trainers would be happy to make the demonstration by the use of video recording.

As we said above, some training centers do not have such equipment, and others have different types which can bring advantages as drawbacks.

3- Observations and analysis

Our analysis will be based on four kinds of observations on simulators equipped or not of video systems. The four kinds of simulation training sessions are linked with the following jobs:

- aircraft pilots of a big European company,

[*] This work has been initiated in 2008 and the result have been gathered in an internal report of the Lab. of Research for Sc. in Energy (2008), reference: LA/./rapint-video01 ind00

- commercial navy officers for big ships and vessels of a European country,
- nuclear reactor pilots of a big European company,
- anesthetist's training at a European university and medical center.

For commercial navy officers and aircraft pilots, no video systems are available, but of course, trainers would like to have one; if they do not, it is not only a question of cost. Until recently, it has also been a question of performance of the systems, which have, for a long time, been based on tape recording video (we shall discuss about the drawbacks of those facilities farther). As we said, it has not only been a question of money: the aircraft trainers made several years ago some tests with cameras fixed inside the cockpit, but the cockpit is so narrow that is was quite difficult to find the right place for the cameras, and the records obtained at this time were not good enough to be exploited correctly. It means that using cameras for video recording implies the previous and careful study of the simulator in order to identify the relevant location of cameras.

4- Use the whole record or not?

Usually, the whole session on simulator is recorded, which is a good thing, because we never know in advance all of that could be useful during the debriefing. But, must the trainer watch the whole time recording with the trainees? Usually no, except for specific reasons, like the self and cross-confrontation developed by the French Work Psychology stream (Clot et al., 2002; Fauquet, 2008). Another specific reason can yield the trainers to watch the whole time records, but without trainees: this is what we did the past year with anesthetist trainers, in the frame of some researches concerning stress and its implications during training sessions on simulators (Fauquet & Frémaux, 2010, Fauquet-Alekhine et al., 2011). But for the debriefing following the simulator training, it is clear that this must not be done for the following reasons:

- The debriefing must be a space of time for discussion; only this discussion (we mean the effort made by everyone to bring into words the thoughts of what they did or not) will lead them to a progress in their work activity (Dejours, 2000; Clot et al., 2002; Fauquet, 2006; Fauquet, 2008). Thus, spending time watching the simulator movie is a waste of time.
- The video record must help the trainer in the demonstration of a fact, in the aim of a pedagogical goal. As we noticed above, sometimes, trainees are not convinced of what is said or reported during the debriefing, even if it is done by their peers rather than by the trainer. In such a case, the trainer needs to make the demonstration by the movie. And in such a case, watching the whole recorded movie is not useful: just the few minutes concerned by the situation must be used.

As we see, the video record must be used just in a punctual manner; it is a help for the debriefing while the debriefing is not the opportunity to see what has happened on the screen in a passive way. The debriefing must remain a time of collective discussion.

5- Tape record or numerical record?

Despite the technological progress concerning video systems, numerical facilities compared to tape recording facilities are still much more expensive. The question then is : must we decide in favor of tape records for a question of price ? The answer is definitely NO. If a training center do not have enough money to provide a numerical system, the best is to wait for the price to go lower, because, with the tape record system, money will be lost as a waste of time. The following example will help to understand why.

It concerns the nuclear pilots' training. Some observations have been done since more than ten years on the same training center. During this time, the video facilities have changed, from the tape recording system to the numerical system. And we have been lucky enough to use both of them. The difference has been done very fast in favor of numerical facilities.

With the tape records, time had to be noted on a sheet of paper, since, as we explained above, the whole record must not be used, but just some few minutes here and there; thus, it is necessary to be able to find the sequences which are of interest. When this was done during the simulator session, then, during the debriefing, finding the right sequence in the tape record was rather hard, and was taking the time of the trainer during which trainees were waiting. This was not a problem when there was just one sequence to be shown: in such a case, the tape could be prepared during the time break planned between the simulator and the debriefing. But when several sequences were needed, it was rather difficult for the trainer.

Today, the training center uses numerical system. It is quite different; should we say : it is like the heaven compared to the previous system ? During the simulator session, trainers can make observations and, with a simple click, put a time index on the time line of the record to notice what is of interest for them later during the debriefing. And they can associate a title to this index, in order to find it more easily later. This allows them to have quasi instantaneous access to the sequences of interest during the debriefing, and even to several sequences.

6- Camera characteristics

The zoom accuracy of the camera must be chosen with regard of what is planed to obtain by the trainers. It depends of the kind of job for which people are trained, and it depends of the size of the room where the training session takes place.

If we consider the aircraft simulator, the distance between the camera and an object far from it can be around 2 meters. But if we consider the nuclear reactor simulator, it can be 10 meters. Concerning anesthetist and navy officers, distances can be between those two extremes. So, we can see that the choice of the camera will be quite different from one case to another, just because of the room size.

Another point is the one of the objects that may be of interest. For the case of nuclear reactor pilots, experience has shown that it was quite comfortable for the trainer to be able to make a zoom to specific points like the sheet of paper on which the pilot is writing, or on a given indicator that a pilot is trying to read. This of course must be coupled with another functionality which is the possibilities of movement of the camera: zooming means pointing a specific target, and so, high accuracy must be chosen only if the camera is equipped of moving remote control.

7- Ambiance or individual microphone?

Most of facilities provide a full audio-video system with ambiance microphones. This can be convenient for the anesthetist simulator, or sometimes, for the nuclear reactor pilots, because they are working in a low sonorous ambiance, and their voices are audible. Yet, on reactor simulators, it has been chosen by the company, since a long time, to have individual microphone for each of the people trained in the piloting simulator, so that the quality can be every time as good as possible.

For the aircraft and navy simulators, it is quite different since the full scale simulators reproduce the sound of the engine: to be more realistic, this choice has been done, and thus the trainees can have a closer feeling on simulator to the one they have in non simulated situation. Furthermore, on the aircraft simulator, when the cockpit is moving as it is supported by hydraulic jacks, some sonorous vibrations can be heard inside the simulator: if there is no individual microphone, it can be difficult to hear the pilots' voice. But these are just assumptions based on the observations made, because the company we have worked with has not yet equipped the simulators of audio-video facilities.

The conclusion is that if the simulated situations are noisy, individual microphone must be chosen.

8- Telephone discussions

According to the job concerned by the simulation, telephone or HF radio will be used for discussion between the trainees and others involved in the process of the simulated job. Usually, the "others" are played by the trainers during simulator sessions. When the discussion takes place via the radio, there is no problem most of the time to record the whole conversation with the microphone, but when the telephone is involved, one part of the exchange is missing, and this can be a drawback because, most of the time, operational communication is a parameter of great importance (Fauquet-Alekhine, 2009, 2012b) that must be used during the debriefing if needed.

On the nuclear reactor simulator, this option was not available at first within the numerical facilities, and our observations have quickly lead to put this as an effective mean of the system. Thus, the telephone line must be recorded on one track.

9- Movie distribution or not?

The question concerns what must be done with the recorded movies obtained during the simulator sessions. As it has been exposed above, those movies are of course used during the debriefing. But after, what must be done with them. One can think that it will be a good idea to provide the movies in a common format to each trainee, for further analysis. It means then that every of them will be able to show his own job on the computer to the people he wants. Of his own job, but of the colleagues' job too! And this is the problem! From the ethic standpoint, and in some countries from the legal standpoint, it is forbidden to put this sort of audio-video material at their disposal. And from the self-esteem point of view, it can be a problem for some people of the trained team. The problem comes from the fact that people are not so much used to watch themselves on the TV screen, neither to hear their own voice. And for some of them, it can be a problem: the problem of a metallic voice, a problem of clothes not so nice, a problem of stoutness or baldness; we have observed some case of debriefing blocked just because of self physical discovery on the movie (Fauquet-Alekhine & Pehuet, 2011).

A second problem is related to the future position of the trainees. If among the trainees stands a future manager, it will be possibly difficult to say things that could trouble him/her.

To cope with these kinds of problems, the nuclear company has written in its organization documents that all records would serve only to the session in progress: records are then deleted after each session. For the anesthetists, the trainers co-sign a letter with every of the people trained on the simulator, before every session; in this letter, trainers engage themselves not to distribute the video, to use it only in a research goal, and to treat the data with an anonymous approach.

Experience has shown that it is much better not to distribute the files of the records, and that trainers must always keep a hand on them. This is suggested for the legal standpoint, for self-esteem, and also for pedagogical considerations.

10- Concluding advice

We can now gather advice from these above comments.

A previous and careful study of the simulator is necessary in order to identify the pertinent location of cameras.

Those cameras are link to a recorder. Even if tape recordings are low cost, they must be avoided because they are too heavy to use. The numerical record system must be chosen, and in case of lack of money, it is worse to wait for the price to be lower. Experience has shown that using a tape recorder is most of the cases a waste of time.

The zoom accuracy of the camera must be chosen with regard of what is planned to obtain by the trainers. It depends mainly on the room size and on the target which has to be seen by trainer. High zoom accuracy must be coupled with moving remote control of the camera.

Concerning the audio system, if the simulated situations are noisy, individual microphones must be chosen. And if exchanges between people involve discussion on the telephone, the telephone line must be recorded on one track.

The trainer must not watch the whole time recording with the trainees during the debriefing, except for specific reasons, like the self and cross-confrontation, or other reasons like specifics researches, which do not involved the trainees most of the time.

And finally, it is much better not to distribute the files of the records, and trainers must always keep a hand on them. This is suggested for a legal point of view, for a self-esteem point of view, and also for the pedagogical point of view.

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