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

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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.

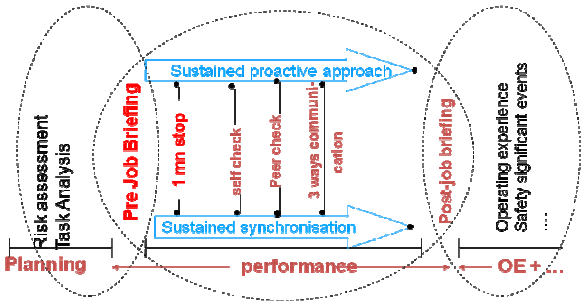

Fig. 1. The six Human Performance tools expected to be part of professional practices, presented according to the three work activity phases: planning, performance, operating experience.

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.

a b

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

a b

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

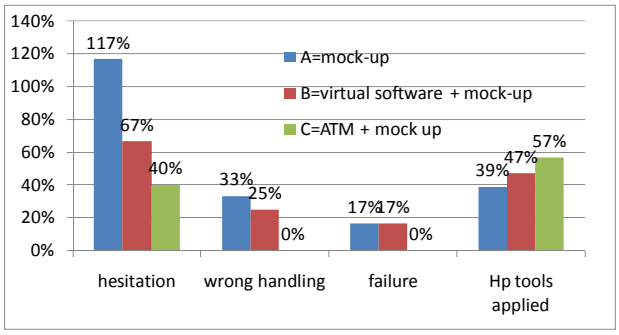

Fig. 6. Subjects' efficiency according to the task configuration.

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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