British Journal of Education, Society & Behavioural Science
14(2): 1-17, 2016, Article no.BJESBS.23607
ISSN: 2278-0998

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Decontextualization Effect in Simulation Training for Transverse Professional Practices

Philippe Fauquet-Alekhine[1,2,3]* and Anne Boucherand[1]

[1]Nuclear Power Plant of Chinon, BP80, 37420 Avoine, France.
[2]Laboratory for Research in Science of Energy, Montagret, France.
[3]Department of Social Psychology, London School of Economics and Political Science, Houghton St., WC2A 2AE, London, UK.

Authors' contributions

This work was carried out in collaboration between both authors. Author PFA wrote the first draft of the manuscript. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/BJESBS/2016/23607
Editor(s):
(1) Chih-Wei Pai, Taipei Medical University, Taiwan.
Reviewers:
(1) P. Moodley, University of Pretoria, South Africa.
(2) Milton Rosa, Universidade Federal de Ouro Preto, Brazil.
Complete Peer review History: http://sciencedomain.org/review-history/13090

Original Research Article

Received 9th December 2015
Accepted 4th January 2016
Published 27th January 2016

ABSTRACT

Whereas full scale simulators operated for contextualized simulated training sessions are widely used for occupational training, studies undertaken regarding virtual applications have shown that decontextualized simulated situations could be used as a relevant lever to help trainees improving professional skills. This was here quantified and analyzed through three different experimental conditions (two included virtual training, contextualized and decontextualized) summoning *N*=33 experienced workers. A pre-analysis for experiment design helped us to define necessary features for decontextualized design with the objective of successful occupational training. Analysis of the benefits induced by each experimental condition was undertaken through comparative assessment of trainees' performance after training. Results showed that, when respecting aforementioned specified features for experienced workers, decontextualized simulation training could significantly increase performance compared to contextualized training. This phenomenon was discussed both from the psychological and neurophysiologic standpoints.

**Corresponding author: E-mail: larsen.sciences@yahoo.fr;*

Keywords: Vocational training; high risk industry; decontextualization; simulation; learning transfer; performance; professionalism.

1. INTRODUCTION

High risk industries (in the sense given by Amalberti [1]: systems of high technology operated by human beings and involving risks like accidents as well as human errors (11-12)) are usually designed from a simple technical idea to answer a basic need. For example, the purpose of a nuclear power plant is to produce electric energy from nuclear energy. From the very simple idea which is the fission of atoms, heat is obtained and used to transform liquid (usually water) in gas under pressure for it to make a turbine and alternator rotating to produce finally electricity. Unfortunately, the technical achievement of such a simple idea remains complex and leads to the elaboration of a complex technical system that may give rise to safety problems [1-4].

To make this complex technical system operate, women and men are needed within an organization which is also complex. The complex technical system becomes therefore a complex socio-technical system [5: 25].

The efficiency and the improvement of safety and reliability of such complex socio-technical systems are based in part on the professionalism of the workers. The professionalism (competence or skill expected of a professional [Oxford dictionary]) is elaborated through professional training within a professionalization strategy for which high fidelity simulation training (using full scale simulators most of the time) has become a central resource [6]. Here, professional training must be understand in the sense suggested by Van der Heiden et al. [7] based on the work of Genderen (who outlined the differences between education and training) [8]: "the objectives of training are primarily to teach individuals to carry out specific tasks based upon an accepted methodology and for which known techniques are available" (44). Many professions are concerned such as Nurses [9], Anesthetists [10-15], Surgeons [16-18], Aircraft pilots [19], Flight fighters [20], Nuclear reactor pilots [21-25], Robotic pilots [26-27], Merchant navy captains [28]. In early times, full scale simulator designers were focusing on technical aspects and therefore conceived simulators with high fidelity as close as possible to the real operational situation. The well-known twentieth century educational specialist Edgar Dale (1900-1985) who developed the Cone of Experience [29] was suggesting in 1944 basic proposals of effective teaching among which "making the learning situation as real as possible" [30: 204].

Full scale simulators integrate nowadays socio-technical approaches since the pioneer studies of Rasmussen [31]. This improvement seems to have contributed to shape the central role of today simulator training [32].

However, with the recent and fast progress provided by computer science, virtual applications, developed since long for occupational training but suffering of a lack of realism compared with real operating situations or tackling high financial cost, are now improved and accessible for lower cost. In parallel, many studies are now available regarding the specific or general effects of such training facilities, the relationship between trainees and software and between subjects through the software [33-37], about the effect of pedagogical agent also called avatar [35,38-39], the effect on the collective work or leadership [34] or the benefits for specific professions, especially for medical jobs [40]. Reviews are available on the subject (see for example [41]). All these studies suggest that virtual simulation offers a broad range of possibilities in which sensorial system can be quickly stimulated by the software which triggers imagination and may lead the trainees to faster improvement not only because of the pedagogical content of the software, but also because of the pleasure it gives to the subject. All these possibilities may occur despite the decontextualization of simulated situations offered by virtual applications. Even more: decontextualization may be used as a lever of improvement [42].

Despite the importance of (de)contextualization of simulation illustrated by these considerations, the literature is devoid of study about this point. On the contrary, designers of high fidelity simulators aim at reducing the distance between the simulated situation and the real operating one, that means to increase the degree of contextualization. This is done both from a figurative standpoint centered on the real operating situation, and from an operative standpoint centered on the work activity [43].

This paper aims at contributing to estimate whether decontextualization of simulated situations (as opposed to the context of real operating situations) may give benefit in controlled conditions in terms of performance when trainees come back to real operating situations.

For this aim, three experimental conditions were elaborated, one without prior training phase and two with prior training phase, all of them involving subjects in the same final activity: the configuration of a real hydraulic circuit ("real" is here opposed to "virtual"). Subjects performing this final activity (or targeted activity) were assessed in terms of performance according to four criteria. The performance difference between the three experimental conditions helped us to obtain elements of conclusion.

2. MATERIALS AND METHODS

2.1 Design

2.1.1 The decontextualizing approach

Decontextualizing the work activity for simulation training is not a simple approach. It first tackles the possible negative reaction of trainees that denounce very often any discrepancies between the simulated situation and the real operational situation (see example described in [44] §3.4.1, p.80). As explained in §1, trainees put themselves resolutely in the most accomplished high-fidelity simulation perspective, as do most designers, as if this was an absolute necessity to ensure the quality of training. Their criticisms mainly concern the failure of the "simulator as a tool" to reproduce what would happen in a real operational situation; to a lesser extent, their criticisms relate sometimes to the trainers' difficulty to play the role of those who interact with them in a real operational situation (see on this topic the analysis of social interaction in simulation by Fauquet-Alekhine [37]). The first point lies on the technical dimension of their profession, the second point lies on the socio-organizational dimension. The first point is crucial to work the decontextualization of the training session: it indicates that any attempt of decontextualization that can be interpreted as an inability of the "simulator as a tool' to reproduce what would happen in a real operational situation will probably induce a rejection of the simulated situation by the trainees, impacting the effectiveness of the training session. The decontextualized simulation must therefore be clearly distinct from the contextualized situation. A solution may be to undertake decontextualization by designing a simulated situation that does not relate directly or explicitly to their profession. For example, asking a nuclear reactor pilot to participate in decontextualised training session on a full scale simulator of petrochemical station control room leads to a problem: they are both two different situations (e .g. different raw material, different output, different human-machine interfaces in terms of details, different industrial risks by the nature of the potential danger) and similar (e .g. similar social interactions, close imperatives for industrial safety and security, similar kinetic process and related physical phenomena, similar human-machine interfaces in the overall, similar industrial risks by the consequence of the potential danger on human lives). By contrast, asking a nuclear reactor pilot to participate in decontextualised training session on a full scale flight simulator does not lead to any problem because the difference is sufficient not to invoke the discrepancy between the simulator and the real operational situation associated with the trainees' profession (e .g. different raw material, different output, different human-machine interfaces in detail as well as in the overall, different kinetic process and related physical phenomena, different industrial risks, different social interactions, close imperatives for industrial safety and security, similar industrial risks by the consequence of the potential danger on human lives). The question which arises, and on which we will come back below, is how to remain relevant for a decontextualised training session with such differences?

Two other dimensions are involved in the decontextualization approach: the social valuation dimension and the attraction dimension. Regarding the social valuation of the training session, analysis of trainees' feedback in vocational training showed that if trainees feel "infantilized" or "patronized" (these are their own words), they do not get involved in training and are not ready to learn. In the above example where decontextualization offers nuclear reactor pilots to be trained on a flight simulator, the simulated situation relates to a socially valued profession and this facilitates the acceptance of the situation by the trainees. We could also consider a simulated situation socially valued by the values it conveys, such as improving safety, struggling for good against evil or helping someone. The attraction dimension also contributes to promoting acceptance of the decontextualised simulated situation [33]. This dimension may be based for example on the social valuation dimension (being attracted by a socially valued profession), on the power conferred by the situation (being the boss) or the playful dimension (case of Serious Games).

Taking into account all of these elements and to answer the question of how to stay relevant in decontextualized training sessions, it appeared easier to decontextualize transverse professional practices which do not directly concern the trainees' technical gesture, these that apply in various situations regardless of the technical gesture; these could be working methods (e.g. decision making, problem solving) or some of the so-called non-technical skills.

2.1.2 Application to experimental design

The experimental context referred to hydraulic circuits on nuclear power plant and involved workers of two French Nuclear Power Plants (NPP) as participants. Three facilities were used: a mock-up (device #1) built as a full scale industrial facility associated with an activity aiming at configuring a hydraulic circuit, and two virtual applications, device #2 being a virtual replica of the mock-up (used for contextualized training) and device #3 presenting no link with the hydraulic circuit (used for decontextualized training, operated for transverse professional practices improvement and summoning values related to helping someone). These facilities helped us to elaborate three different experimental conditions A, B and C described below. These experimental conditions involved individually participants identified as "experienced workers" as they all had been trained and had a professional experience regarding the tasks which were performed and regarding the competencies required for it. Undertaking experiments in three conditions helped us to analyze the influence of decontextualized training on performance.

2.1.3 Protocol

Participants were randomly assigned to one of the three conditions, A, B or C. Each participant was involved individually in one condition and tackled only one condition: after a presentation of the experimental condition including the expected result of the task and the assessment criteria, each participant was asked to achieve the task as fast as possible.

In condition A: The participant was given a paper procedure and asked to apply it for hydraulic configuration on a mock-up. Details are given in §2.2.

In condition B: The participant sat in front of a computer on the screen of which virtual replicas of the mock-up and of the procedure were presented. The participant was asked to apply the procedure for virtual hydraulic configuration. Then the participant was conducted to the physical mock-up. Here the participant was given the paper procedure and asked to apply it for hydraulic configuration on the mock-up. Details are given in §2.3.

In condition C: The participant sat in front of a computer on the screen of which a virtual application for ATM use was presented and an associated procedure. The participant was asked to apply the procedure for virtual ATM tasks. Then the participant was conducted to the physical mock-up. Here the participant was given a paper procedure and asked to apply it for hydraulic configuration on the mock-up. Details are given in §2.4.

For each condition, the researcher assessed the participant's performance when involved in the final activity according to the performance assessment protocol described in §2.7.

2.2 Apparatus and Procedure for Condition A

Device #1 was a mock-up representing a full scale industrial facility similar to a real operating hydraulic circuit of NPP (Fig. 1) with additional traps compared to the real operating conditions for research purposes. This mock-up presented ducts and valves to be adjusted according to a procedure in order to obtain a sample of clear water. This had to be performed knowing that valves and ducts were connected to a clear water tank or to a colored water tank. In case of a mistake regarding manipulation of the valves, the sample was spoiled by ink. Functional marks (the labels) written on tags identified each piece of equipment on the mock-up. Labels were similar to those used on nuclear power plants: one number, three letters, three numbers and two letters. Some valves were tagged with rather similar labels, similarity exacerbated for research purposes, and therefore constituted the additional traps. For example, valve "1SIV104VR" could be confused with valve "1SIB104VR". This could therefore give rise to mistakes.

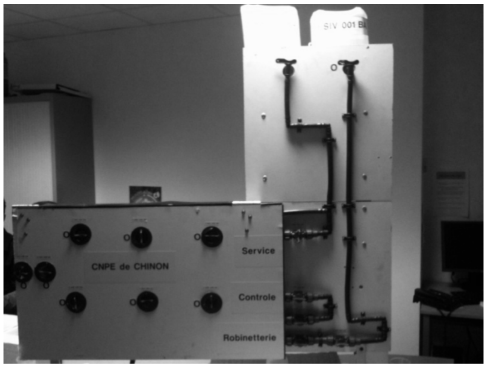

Fig. 1. Picture of the hydraulic mock-up: on the right, visible ducts and valves; on the left, only valves are visible

Hydraulic lines could not all be seen (Fig. 1) by the subject: part of the circuit where lines were interlaced was hidden by a board and just valves and associated tags were visible.

The procedure given to the subjects to perform the circuit configuration was similar to the procedure used at the nuclear power plant.

Subjects involved in performing the task of circuit configuration had to apply Human Performance tools (HP tools) as in real operating situations. HP tools designate six professional practices helping workers to make their interventions more reliable. They may be briefly described as follows [5]:

- The Pre-job Briefing: takes place after the preparation of activity, a specific phase of mental preparation and coordination for the persons doing the intervention.
- The “Take a Minute”: takes place on the workplace and just before it starts, it asks workers for analytical look at the work environment.
- Self-check: involves sequential reading of the procedure identity tag and its corresponding tag on the equipment before the implementation of an action.
- Peer-check: another person verifies the agreement between the intention announced and the draft of the forthcoming action.
- The activity Debriefing: at the end of the activity, it presents positive and negative points of the activity.
- Reliable communication or 3-way communication: to ensure that information has reached the consciousness of the person doing the intervention by repeating information received and confirming it.

Experimental condition A involved only device #1. Subjects were asked to perform the hydraulic configuration activity and apply HP tools. Subjects involved in condition A constituted the control group.

2.3 Apparatus and Procedure for Condition B

The chemical mock-up was reproduced by means of a software (device #2) as well as the procedure (Fig. 2). The choice consisting in reproducing the mock-up with a high degree of fidelity was made in order to conform to the elements given in §1 describing the expectation of industrial trainers and trainees to be trained with tools offering this level of fidelity.

The chemical virtual application (device #2) allowed to carry out the same task than on the chemical mock-up (device #1), and similarly, the subject was asked to implement HP tools. This device #2 was presented to the subjects as a virtual training simulator in order to obtain better results on device #1. The experimental condition B thus consisted in performing the task on device #2 and then on device #1. An avatar allowed oral exchanges whilst performing the task in order to apply some of the HP tools. According to previous work [35], the avatar was chosen female and peer (as a co-worker) rather than a teacher in order to get better results from the trainee. The design took into account research results linked with virtual training software: Beale & Creed [38] noticed that results with virtual training software depended on the role played by the agent and 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 [45], quoted by Beale & Creed [38], 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.

To summarize the expected activity on device #2: subjects had to apply a virtual procedure to realize the hydraulic circuit configuration on screen in order to obtain a virtual sample of clear water, and whilst performing the task, subjects

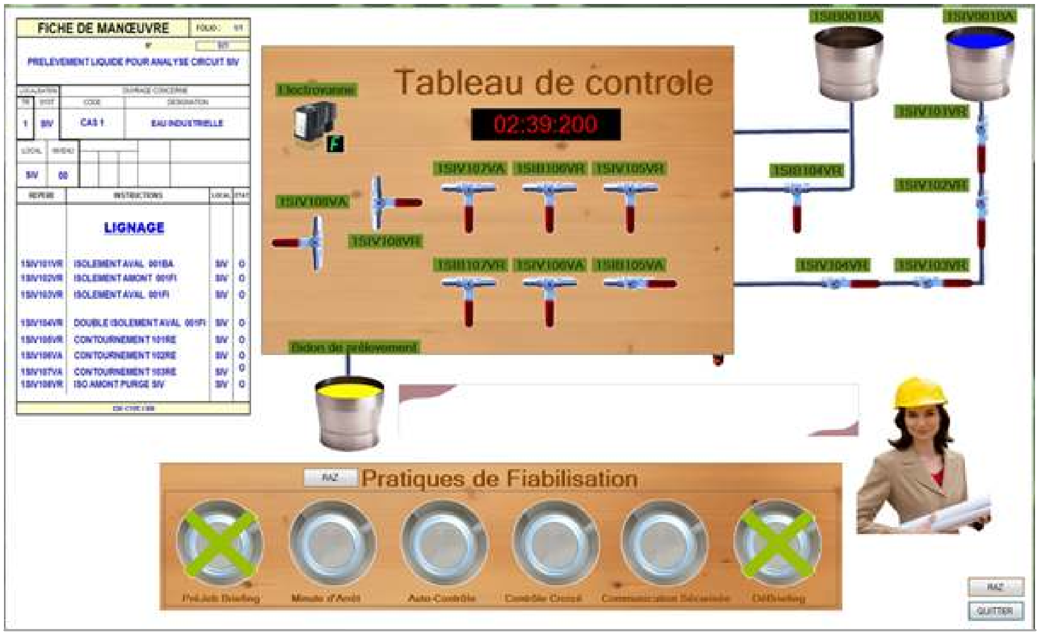

Fig. 2. Screen presentation of the chemical virtual application reproducing the chemical mock-up and the procedure. An avatar is also available by times if exchanges with colleagues are necessary

were ask to apply HP tools. Activity on device #2 was considered as a virtual contextualized simulated operating situation and as a prior training phase before performing the real operating activity on device #1.

Experimental condition B involved the sequence {device #2 + device #1}. Subjects involved in condition B performed task on device #1 just after having performed task on device #2. Subjects were asked to perform the activities and apply HP tools.

2.4 Apparatus and Procedure for Condition C

Device #3 was a decontextualized simulator of virtual activity when compared to activity on device #1. This was an education game aiming at helping people using the ATM device (home screen on Fig. 3) available for free in English version on the Grey Olltwit Educational Software (retrieved in 2014 from www.greyolltwit.com and still available in 2015). We operated it with French subjects not used to reading or speaking in English with the following scenario: the subject had to imagine being on holiday in England and was asked for help by an old woman using the ATM according to a check-list she gave him/her: change PIN code, view balance account on the screen, withdraw £50 with and without a receipt, print a statement. A sample of translated sentences English-French was given to subjects. Subjects had to apply HP tools as in conditions A and B. The task was presented as an opportunity to be (re)trained on HP tools before performing the task on device #1. Hence participants were trained for professional transverse practices (HP tools) conversely to what was done in condition B which trained participants for their professional core practices (hydraulic configuration). This choice was done in order to conform to the elements given in §2.1.1.

Experimental condition C involved the sequence {device #3 + device #1}. Subjects involved in condition C performed task on device #1 just after having performed the task on device #3. Subjects were asked to perform the activities and apply HP tools.

2.5 Comments Regarding the Training Debriefing

Debriefing of simulation training sessions is a key point as a transference process [46-50]. According to Fanning and Gabba [46], debriefing as a transference process bridges the “natural gap between experiencing an event and making sense of it” (116) by involving the trainees in a reflexive analysis of their activity. According to Jones & Alinier [51], debriefing as “reflective practice is a key tenet and an integral component of simulation-based learning outcomes” (325). Previous works [52] quantified the performance increase induced by a training debriefing before performing the targeted activity in real operating situation. In the line of these studies, it would have been logic to include in condition B (resp. C) a training debriefing after activity on device #2 (resp. #3) and before activity on device #1. Nevertheless, the aim of the present study was to assess the difference induced by (de)contextualization on the participants’ efficiency whilst performing the targeted activity on device #1. Therefore, we found relevant to reduce any factor influencing this efficiency and chose not to include a debriefing of the prior training phase in the studied conditions and avoid a bias due to the debriefing. Conditions B and C involved participants in the activity with virtual application and just after in the targeted activity without intermediate debriefing.

2.6 Subjects

Participants, all volunteers to perform the tasks, were "experienced workers" (*N*=33, 9% female, under-represented because few involved in the industrial professions considered in this study): they were workers from operational trades, used to working in the field and monitoring hydraulic circuits, handling or at least being in contact with taps and valves, working with (even elaborating for some of them) modus operandi, trained to apply Human Performance tools (HP tools) whilst working. Novice workers were not considered here as it was shown that prior training on virtual application used as warm-up before the real operating situation could give significant benefits for experienced workers but not for novice workers [53].

Subjects were assigned randomly and individually to the experimental conditions. Each subject tackled just one condition, was ask to perform the task as fast as possible and was updated about performance assessment protocol.

2.7 Performance Assessment Protocol

For each condition, performance was evaluated for the task performed on the device #1 (the targeted activity) as it was the activity for which subjects were trained in conditions B and C. Performance rating was carried out according to four criteria:

- Failure,
- Wrong handling,
- HP tools applied,
- Hesitations.

Obtaining a clear sample of water was a success while colored water referred to a failure.

Fig. 3. Overview of the home screen of the ATM application retrieved for free from www.greyolltwit.com

A wrong handling referred to the subject not immediately handling the right valve, e.g. did not turn it as required or begun to handle the wrong piece of equipment but then made a correction. The number of wrong handling was counted.

Application of HP tools was assessed regarding the number of different HP tools used by each subject among the six expected and expressed as a proportion knowing that a maximum of six HP tools were expected.

Hesitation referred to the subject touching the wrong piece of equipment. Hesitation was considered as a symptom of decreasing performance (increasing the duration of realization of the task). The number of hesitations was counted.

All data were considered in terms of proportion of the total population of the sample in order to compare the results between conditions.

2.8 Comments about Performance Hypothesis

The experiment design was presented during a seminar at the Dept. of Social Psychology (LSE, London, UK). The dozen of researchers attending the presentation was asked which condition would give the higher performance in their opinion (i.e. an a priori opinion without in-depth analysis). More than 70% suggested that condition B would have the highest score (effect of the "high fidelity" virtual application), followed by condition C (effect of training) and then condition A (no preparation).

The experiment design was also presented to managers of the Chinon NPP. They were asked the same question. Nine managers over ten attending the presentation suggested that condition B would have the highest score for the same reason than this of the researchers.

3. RESULTS

Fig. 4 gives performance results for the three experimental conditions.

Statistical calculation applying t-test of Student and size effect analysis according to Cohen's criteria [54] allowed us to estimate the significance of the data (given below) and to characterize size effect as medium.

Overall, the best performance was obtained for condition C ($p<.01$):

- Hesitations increased from condition A to conditions B and C ($p<.03$) whereas the difference between conditions B and C was not significant,
- Wrong handling decreased from condition A to B ($p<.01$) and decreased again from condition B to C ($p<.1$),
- Failure decreased from condition A to B ($p<.01$) and from condition B to C ($p<.1$),
- HP tools application increased from conditions A and B to condition C ($p<.01$) whereas the difference between conditions A and B was not significant.

Correlation analysis showed only two significant values for virtual ATM application with HP tools application ($r=.45$, $p=.007$) and for wrong handling with failure (($r=.82$, $p=.000$).

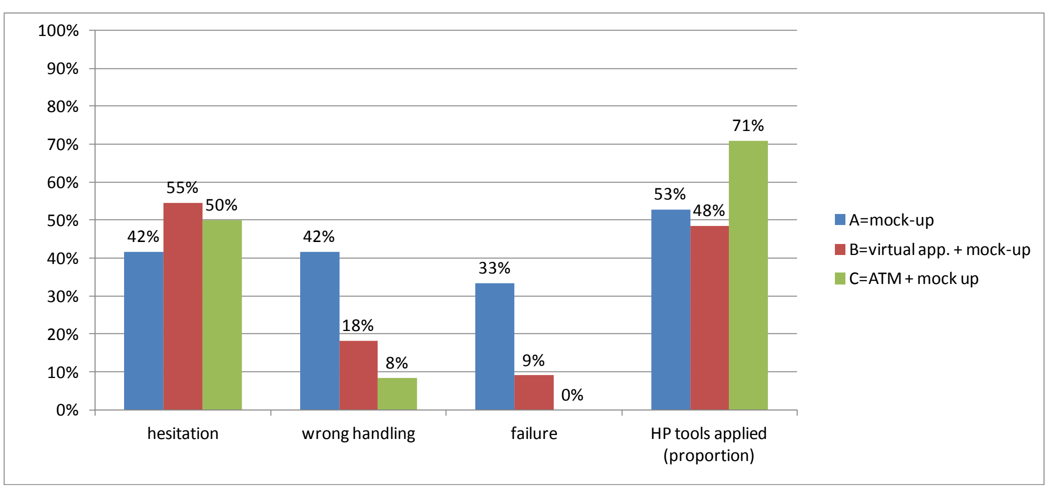

Fig. 4. Comparison between results of the three experimental conditions

Analysis of experience or age showed no significant influence on success or failure. Analysis of gender influence was not possible due to the under-representation of female participants.

4. DISCUSSION

4.1 General Comments

Here it must be borne in mind that participants were experienced workers. They had been trained or had experienced both transverse professional practices (for HP tools application) and professional core practices (for hydraulic configuration). Hence they could be considered as competent to work without any training prior to performing the activity on the mock-up in condition A.

It was not surprising that the poorest performance was observed in condition A: the activity in this condition was performed without any prior training conversely to other conditions, and the mock-up presented additional traps compared to real operating conditions that generated difficulties and contributed to producing greater differences in results. Performance would have been much better in real operating conditions at the NPP since these kinds of traps are avoided. Other studies in medicine showed that a prior training phase (or warm-up) on virtual application contributed to increase efficiency in the real operating situation [55-57] therefore explaining the better performance in conditions B and C compared to condition A.

However, referring to the hypothesis stated in §2.8, it was surprising to obtain better results in condition C rather than in condition B.

4.2 Explaining Subjects' Performance

Explaining the better performance with prior training (conditions B and C) versus no prior training (condition A) was done elsewhere (see §4.1) and this finding was rather trivial. This will not be discussed here. What is interesting to discuss is the difference of performance between conditions B and C.

The difference between conditions B and C remained in that the training activities were supporting two different pairs of professional practices:

- Condition B supported the professional core practices of the targeted activity i.e. related to competencies for hydraulic configuration. It also supported transverses professional practices associated with HP tools application.
- Condition C supported the professional transverse practices associated with HP tools application and also supported practices associated with using an ATM in a foreign country. The latter practices were not related to the targeted activity and contributed to reinforce the decontextualized character of the simulated situation.

The fact that condition C yielded better performance than condition B means that condition C provided an extra element to the subjects that was not in condition B but contributed to enhance performance or, at the opposite, condition B provided an extra element to the subjects that contributed to reduce the performance. In the following, this is discussed from psychological and from neurophysiologic standpoints.

<u>4.2.1 Psychological approach</u>

4.2.1.1 Extra element in condition C enhancing performance

In terms of providing an extra element to the subjects in condition C that contributed to enhance performance, decontextualized simulation training (condition C) could have filled a training gap or could have been more efficient in terms of occupational training:

- Filling a training gap: During their occupational training curriculum, participants might have been better trained for core practices than for transverse practices and thus might have presented a more pronounced weakness for the latter than for the former. Condition B provided training for transverse and core practices both related to the trainees' profession whereas, in condition C, trainees could focus on transverse practices during the prior training phase since the proposed core practices related to using an ATM for which trainees could feel less concerned. The prior training phase therefore came to enhance "HP tools" competencies. If there was any need of improvement for them, this might have helped subjects to apply

HP tools more often and more efficiently during and after this prior phase, making their actions more reliable, avoiding the traps, and resulting in a better performance in condition C. The fact that HP tools score was higher in condition C (Fig. 4) may be considered as an illustration of this assumption.

- Higher efficiency of the prior training phase: Professor Mavre, from the Institute of Applied Arts in Paris (France) explained that decontextualized training "is all about putting the learner inside a context in which his professional reflexes will be neutralized, allowing to reach for a deeper level of the brain mechanism of an individual" [42: 40]. This proposal summarizes how decontextualization may be related to the zone of proximal development introduced by Vygotsky [58], defining a psycho-cognitive state in which the subjects are about to know how to do, what they have to do but do not yet know how to do: in condition C, the decontextualized simulated situation as unknown situation (compared with hydraulic configuration activity) might have put the subjects in a kind of problem-solving situations (or obstacle-situations in the sense of the Constructivism Theory) "which are professional situations where an operator is obliged to transform her/his repertoire of skills to adapt it to a new professional condition" [59: 81]. Therefore, if the prior training phase provided new skills, these might have been used with benefits in the targeted situation and have helped to increasing performance.

4.2.1.2 Extra element in condition B reducing performance

In terms of providing an extra element to the subjects in condition B that contributed to obtain a lower performance, contextualized simulation training of condition B could have maintained participants' routines in the sense of Rasmussen's SRK model [60-61]. This model suggests the subjects' approach to a task corresponds to three different sorts of behavior:

- Knowledge-based behavior (K), adopted for "unusual" situations "for which know-how is inadequate", implying "deduction of rules by means of a mental model" [60] (259), whilst "hypothetical explanation is formed and tested conceptually before action is taken", "related to the extend and quality of the […] mental model" [61] (62). A high degree of attentional control is required to obtain the necessary understanding of the situation and elaborate solutions in a rather unknown or unfamiliar context. This approach is mainly concerned by errors due to a wrong mental model used by subjects whilst performing the activity.
- Rule-based behavior (R), when the subject "is familiar with the situation and only have few options for action at any given time" [61] (61), composing a sequence of actions "typically controlled by a [internal] stored rule or procedure which may have been derived empirically during previous occasions" [60] (259). Information sought by the subjects is the minimum necessary to discriminate amongst a few options and routines carried out with a degree of attentional control allowing the rule-based analysis necessary to know which options to apply in a fairly familiar context. This approach is mainly concerned by errors due to choosing the wrong options whilst performing the activity.
- Skill-based behavior (S), possible if the context offers the subject all cues needed to know which action to be applied, taking "place without conscious control as smooth, automated, and highly integrated patterns of behavior" [60] (258), and applying "during familiar circumstances" when "sensory-motor routines take care of the direct control of integrated patterns of movements" [60] (61) without conscious control [60] (259). Routines are applied with a low degree of attentional control in highly familiar context. This approach is mainly concerned by errors due to disturbance of subjects or unexpected details or discrepancies compared to what is expected whilst performing the activity.

A revisited approach of Rasmussen's model was presented in a previous study [52], considering these three main patterns inside a 2D-space in terms of attentional control given to the activity and familiarity with the activity: Skill-based behavior is characterized by a low degree of attentional control and high degree of familiarity with the activity, Knowledge-based behavior is characterized by a high degree of attentional control and low degree of familiarity, and Rule-based behavior is between the two.

The results obtained in the present study suggested that the participants, all "experienced workers", had probably approached the task in conditions A and B adopting the Skill-based behavior pattern: they were used to handling taps and valves, working with modus operandi, and trained to apply HP tools, making it a highly familiar context for them and reducing their attentional control. In condition B, a prior contextualized training helped them to be aware of possible traps, probably increasing their attentional control by including as central informative clues those related to the traps identified with the virtual application. In parallel, their familiarity with the activity did not change or was increased, making them more hesitating in condition B than in condition A and avoiding errors (reducing wrong handling; see Fig. 4) and finally increasing performance compared with condition A. In condition B, participants summoned both transverse and core practices from the prior training phase to the targeted activity.

On the contrary, condition C did not contributed to enhance participants' familiarity with the targeted activity. It might even have produced opposite effect by involving them in a quite different activity than the targeted activity just before performing it. In addition, when tackling the targeted activity, participants summoned only the pre-elaborated cognitive schemes associated with transverse practices during the prior training phase, perhaps inducing a higher degree of commitment and/or management in HP tools application, thus effectively increasing HP tools application (see scores on Fig. 4). Both (no enhancement for participants' familiarity and higher commitment in HP tools application) might have generated (or have been combined with) an increase of the level of awareness, moving subjects' approach away from a Skill-based behavior (S), and thus making them less vulnerable to unexpected details or discrepancies compared to what was expected (i.e. aforementioned additional traps in §4.1).

4.2.2 Neurophysiologic approach

Neurophysiologic experiments undertaken by Prof. Y.I. Alexandrov (Laboratory of Neural Bases of Mind, Institute of Psychology, Russian Academy of Sciences, Moscow) with rats (and which results and conclusions may be extrapolated to some extent to Human [62]) permitted to establish that learning is mediated by a process of "behavioral specialization" based on the activation of silent neurons [63-64]. In the frame of the system-selection theory [65], at the neuronal level, learning involving the formation of new behavioral acts is directly related to the formation of new functional systems, i.e. the formation of neuron specializations for these systems [66]: "Neuron specialization consists of the appearance of activation of previously 'silent' neurons every time the relevant formed behavioral act takes place" (139). Neuron specialization concerns early neuronal development stages (e.g. eating, moving) which relate to the motor cortex; it also concerns later learning processes (e.g. writing) which relate to the cingulated cortex.

We may therefore suggest that the decontextualization simulated situation in condition C provided an unusual context for the subjects to learn how to apply HP tools resulting in the formation of a new behavioral act associated with the activation of 'silent' neurons. In other words, experiencing decontextualization simulated situation, a part of the subjects' cortex which was not yet activated (silent neurons) became devoted to the task "applying HP tools" through a new behavioral act.

From the neurophysiologic standpoint, this may be reformulated in suggesting that subjects involved in condition C increased the proportion of neurons activated in the cortex and that this additional activated part was specialized for HP tools application in complement to previous activated part(s). Conversely, subjects involved in conditions A and B were not concerned by this process since they did not form any related new behavioral act whilst applying HP tools: conditions A and B provided only usual situations.

Furthermore, neuron specialization is a long term process involving activation of gene expression to modify functions and connections of neurons [66]. This supposes that the new set of neurons activated through the new situation must be reactivated periodically to remain available. Reactivation does imply tackling this new situation periodically or means being involved in an activity that summons the behavioral act to be re-activated.

4.3 Contextualization vs Decontextualization

In §1 we described a tendency for simulation training designers to seek a simulation situation of high fidelity, as close as possible to the real operating situation from the operative and from the figurative standpoints. In §2.1.1 we also reported that trainees put themselves resolutely in the most accomplished high-fidelity simulation perspective and discussed how the possible trainees' rejection of non-high fidelity simulation training could occur.

In such a context, the possible benefits of virtual applications for learning and training pointed out by several studies (see §1) can hardly be tested, assessed, and applied for occupational simulation training. This impediment was confirmed by discussions regarding assumptions to designate this of the three experimental conditions which would give the highest performance: by the side of the researchers as well as by the side of the industrial managers, contextualized simulation training (condition B) was selected to produce the highest performance (§2.8).

The results obtained in the present study showed that conversely, when respecting specific criteria for transverse professional practices, decontextualized simulation training could be seen not as an advantage compared to contextualization but as a relevant complement and indeed be used as a lever of improvement.

It is clear that other studies of this type are necessary to deconstruct the a priori feeling favoring at the outset any high-fidelity simulation training to the expense of decontextualized training.

However, whatever decontextualized simulation training may offer in terms of additional learning progress for the trainees, it makes more complicated a question of importance in occupational training, this of the trainees' evaluation; this question is more complicated than it may be with high-fidelity simulations. The question is already complicated with the latter because being skillful in a high-fidelity simulated situation does not mean being skillful in a real operating situation (see for instance discussion in [44: 20]); this is why for example aircraft pilots are qualified for a great part on simulators but they are then assessed by a certified instructor in real operating situations whilst copiloting the plane. Therefore, the gap between decontextualized simulation and real operating situation being greater, is the trainees' assessment in decontextualized simulations relevant? The answer would need a study (which is not the aim of the present one) but in our opinion, again this suggests that decontextualized simulation training cannot be disconnected from contextualized simulation training: assessment of transverse professional practices in decontextualized situations does not directly serve the final goal aiming at improving competencies for the real operating situations; this must be followed or combined with an assessment in high-fidelity simulated situations and finally in real operating situations.

4.4 Further Improvement of Performance

In the light of Kolb's well known model [67-69] describing an efficient learning process as a four-stage experiential learning cycle, it is clear that at least one stage is missing in the experimental conditions of the present study. Kolb's model defines learning as a process whereby are involved "two dialectically related modes of grasping experience, concrete experience and abstract conceptualization, and two dialectically related modes of transforming experience, reflective observation and active experimentation" [69] (333). The reflexive observation may be achieved through a training session debriefing which is seen by some researchers as a key point for the transference process of learning on a simulator [46-51]: as mentioned in §2.5, debriefing is an essential component allowing trainees to elaborate competencies which are necessary in the real operating situation. Hence further improvement of performance can be obtained in conditions B and C by reinforcing the transference process through debriefing. Evidences of such improvement have already been obtained [52].

5. CONCLUSION

Experiments showed that decontextualized virtual simulation training, when prior to the real operating activities, could help industrial experienced workers to improve performance. In the present experiments, this improvement could reach about 20% in real operating situations when compared with a context without prior training and about 10% when compared with a context with contextualized prior training.

However the decontextualized character of the simulated training situation respected rules that appeared of importance regarding the feedback obtained through previous training sessions. Not respecting these rules might reduce the efficiency of decontextualization. We suggested that decontextualized virtual simulation training had to be far enough of the technical acts associated with the trainees' professional core practices so that trainees would not denounce the lack of fidelity of the simulated situation and thus consciously or unconsciously reject learning through decontextualization. For the same reasons, we suggested that decontextualized training sessions would address transverse professional practices rather than professional core practices. In addition, we recommended the adjustment of the social valuation dimension and of the attraction dimension of decontextualization. The former relates to decontextualization that considers another profession than this of the trainees for the simulated training situation; in this case, the other profession must be a socially valued profession as perceived by the trainees or must be associated with a situation which conveys values which may be perceived as references by the trainees, such as improving safety, struggling for good against evil or helping someone. The latter relates to features that make trainees find interest in the simulated situation: the social valuation dimension may contribute to it; it may also be features regarding the power conferred to the trainees by the situation or the playful dimension as for Serious Games. All this facilitates the acceptance of the decontextualized simulated situation by the trainees.

Improvement of performance through decontextualization was here explained in terms of filling a training gap and/or in terms of an innovative way to solicit trainees' zone of proximal development. From the psychological standpoint, this could lead participants to re-question their routines in the sense of Rasmussen's SRK model [60-61]. From the neurophysiological standpoint, this could help trainees to improve their efficiency by activating sets of silent neurons as illustrated by Prof. Y.I. Alexandrov's experiments [63-64,66].

Nevertheless, these results must not lead to the conclusion that decontextualization could replace full scale contextualized simulation. We insisted here on the fact that participants were experienced workers and that the improvement was obtained regarding professional practices already elaborated previously. In our opinion, decontextualization training situations must be considered as a complement. Full scale simulators are crucial tools for efficient progress whilst learning new job [35]. In addition, the experimental conditions of the present study did not included debriefing after the prior training sessions. Further improvement of performance can thus be obtain by reinforcing the transference process through debriefing as proved elsewhere in the same conditions [52].

Limits of the present study mainly lie on the fact that rules defining features of decontextualization were elaborated on the basis of the feedback of full scale simulation training sessions obtained in aeronautic, nuclear and medical fields. Other professional fields could help to find out new features. Besides, undertaking a single variable experimental plan could help to better characterize each feature.

Further analysis of the performance obtained in the present study may consider Transformative Learning Theory as a way to understand the increase of performance as an improvement of the learning process [70-71]. However, if the concepts of "autonomous thinking" or "transformations of meaning schemes" of the theory may be easily linked and explained with the present results, it is less clear when considering the concept of "disorienting dilemma" which is central for the theory. Indeed additional analysis would be necessary to consider the results in the light of the Transformative Learning Theory. This work would be worth to be undertaken because, in our opinion, Transformative Learning Theory might highlight other possibilities of decontextualization.

Application of these results and of the conclusions are planned in the beginning of 2016 in order to improve training sessions for experienced field workers at the Training Center of Chinon, in association with Chinon Nuclear Power Plant (France). The preparation phase of this application shows that respecting the rules herein established for decontextualization is a non trivial work that must be carried out carefully not to generate rejection of the training sessions by trainees and at the same time being attractive for them.

ETHICAL APPROVAL

This study received ethical approval of the Ethics Committee of the Dept. of Social Psychology (LSE, London, UK) and has therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

ACKNOWLEDGEMENTS

The authors thank Fr. Daviet, Innovation Project Manager and Simulation Trainer at the Training

Center of Chinon NPP, for his advice and fruitful exchanges. The authors thank all the participants to the experiments and observations. Thanks to Chinon NPP (EDF) for supporting this research program including operating and human tertiary departments and also St. Vallée and Br. Ruf for conception and realization of the mock-up, F. Poyart for software support, Br. Ruf, F. Poyart and S. Draskovic for participation as experimenters. Thanks to the NPP of Bugey (EDF) and especially C. Maruzewski. Thanks to Grey Olltwit Educational Software for free access to educational games. Thanks to Electricité de France (EDF) for financial support.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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