British Journal of Education, Society & Behavioural Science
13(3): 1-13, 2016, Article no.BJESBS.22418
ISSN: 2278-0998

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Innovative Debriefing Protocol for Simulation Training Improvement

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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/2016/22418
Editor(s):
(1) Shao-I Chiu, Taipei College of Maritime Technology of Center for General Education, Taiwan.
Reviewers:
(1) Alexandre Gonçalves Pinheiro, Universidade Estadual do Ceara, Brazil.
(2) Michael N. Nkwenti, University of Yaounde I, Cameroon.
(3) Usman Jimoh Michael, Federal College of Forestry, Ibadan, Nigeria.
Complete Peer review History: http://sciencedomain.org/review-history/12329

Original Research Article

Received 30th September 2015
Accepted 3rd November 2015
Published 18th November 2015

ABSTRACT

Previous multidisciplinary study of vocational simulation training helped us to elaborate an innovative debriefing protocol for simulation training sessions in seven steps applying two key principles (called "debriefing 7S2P"). This study aimed at testing its efficacy and assessing its potential performance. This was undertaken experimentally for simulation training sessions in industrial context gathering novice and experienced workers (*N*=68) to perform individually a simple technical task. The results obtained showed that this debriefing protocol could provide a gain of performance up to 30%. Analysis and explanation were provided thanks to the revisited Rasmussen's SRK model [1] and Kolb's experiential learning cycle [2,3].

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

1. INTRODUCTION

The efficiency and the improvement of safety and reliability of complex socio-technical systems (e.g. industrial plants, healthcare sites) are based in part on the professionalism of the workers, elaborated through a professionalization strategy involving simulation training (Full scale simulators most of the time). This central resource [4] concerns many professions such as Nuclear reactor pilots [5-8], Robotic pilots [9-10], Flight fighters [11], Surgeons [12-13], Anesthetists [14-17], Nurses [18], Aircraft pilots [19]. Many studies are now available regarding benefits of simulation training for these specific professions.

This paper aims to contribute to estimate the benefits of a specific transference process in controlled conditions during simulation training through the assessment of trainees' performance in operating situation. The transference process between simulation training and operating situation was a simulation training debriefing, a key point in the process of simulation learning [20-22]. Our assumption was that the simulation training debriefing as designed in our study would increase performance, and in case of validation, our goal was to rate this improvement in case of a simple technical task.

The operating situation was designed as a context of simple technical task performed on industrial equipment (device #1 described thereafter). This task was to summon two main fields of competencies: "equipment configuration" and "Human Performance" practices application hereinafter referred to as "HP tools application". These are described below. Observations of daily work activities showed that it was easier to handle a valve and read a procedure (equipment configuration) than apply a HP tools (HP tools application) especially for novice workers. Therefore the pedagogical goal of the training phase focused on HP tools. In addition, our intention being to train subjects only on one field of competencies to simplify the simulation training, we chose to (re)train subjects only on "HP tools application" and not on "equipment configuration". To ensure that the field of competencies "equipment configuration" would not be trained, we used a decontextualization application (device #3 described thereafter) for simulation training.

2. MATERIALS AND METHODS

2.1 Design

The experimental context referred to hydraulic circuits on nuclear power plant and involved workers of two French Nuclear Power Plants (NPP) as participants. Two 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 a virtual application (device #3) presenting no link with the hydraulic circuit. These facilities helped us to elaborate three different experimental conditions A, C and D described below. These experimental conditions involved participants divided in two cohorts, one designated "experienced workers" and another "novice workers". The criteria differentiating cohorts are described in §2.7 "Subjects". Undertaking experiments with these two cohorts helped us to analyze the influence of professional experience on performance.

2.2 Apparatus and Procedure for Configuration 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.

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.

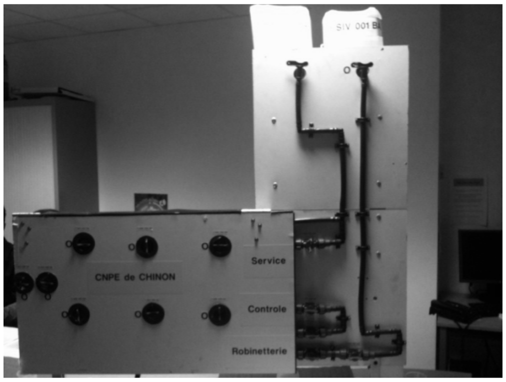

Fig. 1. Picture of the hydraulic mock-up: On the right, visible ducts and valves; on the left, only valves are visible

Subjects involved in performing the task of circuit configuration had to apply 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 [23]:

- 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 involved in condition A constituted the control group.

2.3 Apparatus and Procedure for Configuration 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. 2) available for free in English version on the Grey Olltwit Educational Software (retrieved in 2014 from www.greyolltwit.com). We used 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 condition A. The task was presented as an opportunity to be (re)trained on HP tools before performing the task on device #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.

2.4 Apparatus and Procedure for Configuration D

The last condition D was elaborated on the basis of condition C by adding a debriefing of training between activity on device #3 and activity on device #1. It aimed at improving any transference process between the two activities undertaken on devices #3 and #1 respectively. The debriefing protocol is described and argued as follows.

2.5 Transference Process

Debriefing of simulation training sessions is a key point as a transference process (TP) of learning on a simulator. Fanning and Gabba [20] referring to [21] even said it to be “the most important feature of simulation-based medical education” (115). Anderson et al. [22] also emphasized that “debriefing following a simulation is considered one of the most vital parts of the simulation experience” (62). They gave more than ten references to illustrate the purpose. Stocker et al. [23] proposed that “Debriefing is fundamental to reflection on action and Schön’s theory is that there is a need for participants to challenge their existing frameworks and principles” (7). According to Fanning and Gabba [20], 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. This session debriefing must not be confused with the "activity debriefing" described above among the HP tools. The latter is more closely linked to the After Action Review (AAR) developed by the US army aiming at providing feedback with starting point as a description of what was planned for the mission followed by a discussion of what happened [24].

2.5.1 Debriefing in seven steps

We designed a progressive seven step (7S) protocol for the training session debriefing reinforced by two key principles (2P) from previous collaborative studies [25,26].

This debriefing protocol 7S2P completed and refined the debriefing model of Fanning & Gabba [20] based on the earlier model of Lederman [27], later improved by Rudolph et al. [28] and successfully applied by others (see for example [29]). Fanning & Gabba suggested a three phase debriefing: A reaction phase reducing trainees' emotional stress and giving trainers a preview of their concerns, an analysis phase and discussion of trainees' performance, and a summary phase gathering lessons learned from the experienced situation for future performance.

Two key principles described later on completed the protocol: The generation effect and the projective perspective which benefits have been quantified as generative and adaptive learning process [30].

- **First step:** Remind of ethics concerning the whole training session and particularly the debriefing. This crucial step recalls general considerations regarding the atmosphere of the debriefing, well summarized in the review of Fanning & Gabba [20] (116), promoting a non-judgmental approach.
- **Second step:** Expression of the trainees' expectations and perceived goals of the training session. The final comparison (seventh step) between expectations and what has been done helps participants to leave (and come back) with a positive attitude.
- **Third step:** Trainees' feelings regarding the simulator run. This step was not that important in the present experiments as the activity performed was of an individual type, short, not complex and with a low level of stress. It is quite different when the situation involves several trainees for collective activities, allowing discussion of possible interpersonal difficulties that occurred during the simulator run. This helps deal with eventual consecutive emotional issues (read the example given p.77 in [26]).
- **Fourth step:** Reflexive analysis of the simulator run. This refers to the "reflection on action" of Schön's theory [31]. Subjects reflect after the encountered situation and examine what/how they acted, thought through the problem, which options they chose or which they did not. During this step, the principle of generation effect consisting of making the trainees produce the narrative by themselves is fundamental. This time was also used to clarify technical points according to subjects' questions [32].
- **Fifth step:** Comparative analysis between what had been experienced during the simulator run and what should be encountered in the future operational situation, i.e. for the present study looking for and analyzing the differences and the similarities between the activity performed on device #3 and the following activity on device #1. We referred to this as the "projective perspective": It projects the subject in the future activity and considers what should be done in such forthcoming situation. This was mainly shaped by the principle of projective perspective but also by the principle of generation effect as this was obtained by the researcher's questions which were answered by the subject.
- **Sixth step:** Additional needs in the perspective of transference for the future activity. Subjects were asked whether they needed additional help about any point or not.
- **Seventh step:** Concluding remarks ending the debriefing highlighting what training brought to the subjects, asking the subjects to compare this with the expectations expressed in step 2, and summarizing the subjects' intentions. This dealt with the fact that trainees often have difficulty recognizing the rich learning benefits from the training session [32].

2.5.2 Generation effect principle and projective perspective principle

The generation effect principle aimed at making the trainees produce the material to be discussed, the findings, the solutions and related assessment or admissibility by themselves. As recommended by Thiagarajan [33], debriefing must ensure that the trainees have "discovered and evaluated their own solutions, rather than being told by the leader" (10). The Generation effect was facilitated in this case by the trainer (the researcher) questioning the subjects' narrative, findings and solutions. The generation effect was fundamental during the fourth, fifth and sixth steps described above.

The projective perspective principle aimed at bringing the subjects to project themselves into the future activity on the basis of what they had just done, helping them to think about what should be done in the forthcoming situation. Subjects were thus preparing for the future task by refining the mental representation of the future expected results. The projective perspective was fundamental during the fifth and sixth steps described above.

For research purposes, the "seven steps – two principles debriefing protocol" (7S2P debriefing protocol) was fixed as a series of questions asked by the researcher. This design was necessary in order to work with similar conditions from one subject to another through a structured interview.

2.6 Interview Technique

Two interview techniques were applied during debriefing: Explicitation technique and Activity Theory-based technique. Explicitation technique [34] is when a protocol is put in place by the analyst whereby subjects describe an action they have experienced; it a descriptive implementation of words. This offers a framework and guidelines to lead the researcher in how to conduct the interview in order to make the subject aware of the action and of the way it was performed. This was applied in the frame of a goal-oriented verbalization [35] based on Activity Theory concepts [36-38], an interview technique that seeks the subjects' goals and sub-goals before and whilst performing the activity, making the subject explain the strategies deployed to reach these (sub)goals, usually adjusted in situation to optimize energy according to the principle of cognitive economy [39,40].

Fig. 2. Overview of the home screen of the ATM application retrieved for free from www.greyolltwit.com

2.7 Subjects

Participants, all volunteers to perform the tasks, were of two types:

- Subjects here described as a cohort of "experienced workers" (*N*=46): 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 (HP) tools whilst working.
- Subjects here described as a cohort of "novice workers" (*N*=22) representing the novice subjects regarding hydraulic configuration activity: workers from tertiary trades who had never seen industrial hydraulic circuits except in pictures or during a touristic visit of the nuclear power plant organized by the NPP Department of Communication for the families; none of them had previously neither seen an industrial operating mode nor heard about HP tools.

Subjects from “experienced workers” cohort as well as from “novice workers” cohort were involved in the three experimental conditions. Each subject tackled just one condition.

2.8 Performance Assessment

For each condition, performance was evaluated for the task performed on the device #1 as it was the activity for which subjects were trained in conditions C and D.

Performance rating was carried out according to the expected final result (clear sample of water), number of mistakes made during the activity, and application of HP tools. An additional criterion concerned the number of hesitations.

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). A mistake referred to the subject not immediately handling the right valve, e.g. did not turn it as required. The mistake could be an incorrect handling (beginning to handle the wrong piece of equipment but then making a correction). All data were considered in terms of proportion of the total population of the cohort in order to compare the results between cohorts.

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.

3. RESULTS

Figs. 3a and b give performance results for “experienced workers” and “novice workers” resp. for the three experimental conditions.

Statistical calculation applying t-test of Student and size effect analysis according to Cohen's criteria [41] allowed us to estimate the significance of the data (given below) and to characterize size effect as small except for hesitations and incorrect handling criteria which had a medium size effect.

For the "experienced workers":

- Significantly the best performance was obtained in condition D with debriefing (p<0.01),
- Significantly the worst performance was obtained in condition A, the control condition (p<0.01),
- Prior training with the virtual application and debriefing (condition D) significantly improved performance compared to the control condition A (p<0.01),
- Performance in condition C with the virtual application was slightly inferior to condition D (p<0.1),
- The "hesitations" criterion evolved similarly to the "HP tools applied" criterion.

For the "novice workers":

- Significantly the best performance was obtained in condition D: prior training with the virtual application and debriefing (condition D) improved performance compared to the control condition A (p<0.01),
- Significantly the worst performance was obtained in condition C: prior training with the virtual application with TP (condition C) deteriorated performance significantly compared to the control condition A (p<0.1 to 0.01 depending on the criterion considered),
- The criterion "hesitations" was diametrically opposed to that of criterion "HP tools applied".

Comparing the two cohorts:

- Adding the debriefing to the training process gave significant improvement for both, and condition D gave the best performance for both,
- The control condition A gave the worst performance for the "experienced workers" whereas it was condition C with training on the virtual application that gave the worst for the "novice workers",
- Training on the virtual application gave benefits for the "experienced workers" (without TP), whereas the opposite applied for the "novice workers",
- The "hesitations" criterion evolution of one cohort was the opposite of the other cohort,
- In condition D, "incorrect handling" remained higher for "novice workers" whereas "failures" and "HP tools applied" were quite similar for both cohorts.

Analysis of experience or age had no significant influence on success or failure.

4. DISCUSSION

It was not surprising that poor performance was observed in condition A for both cohorts: the task 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 since these kinds of traps are avoided.

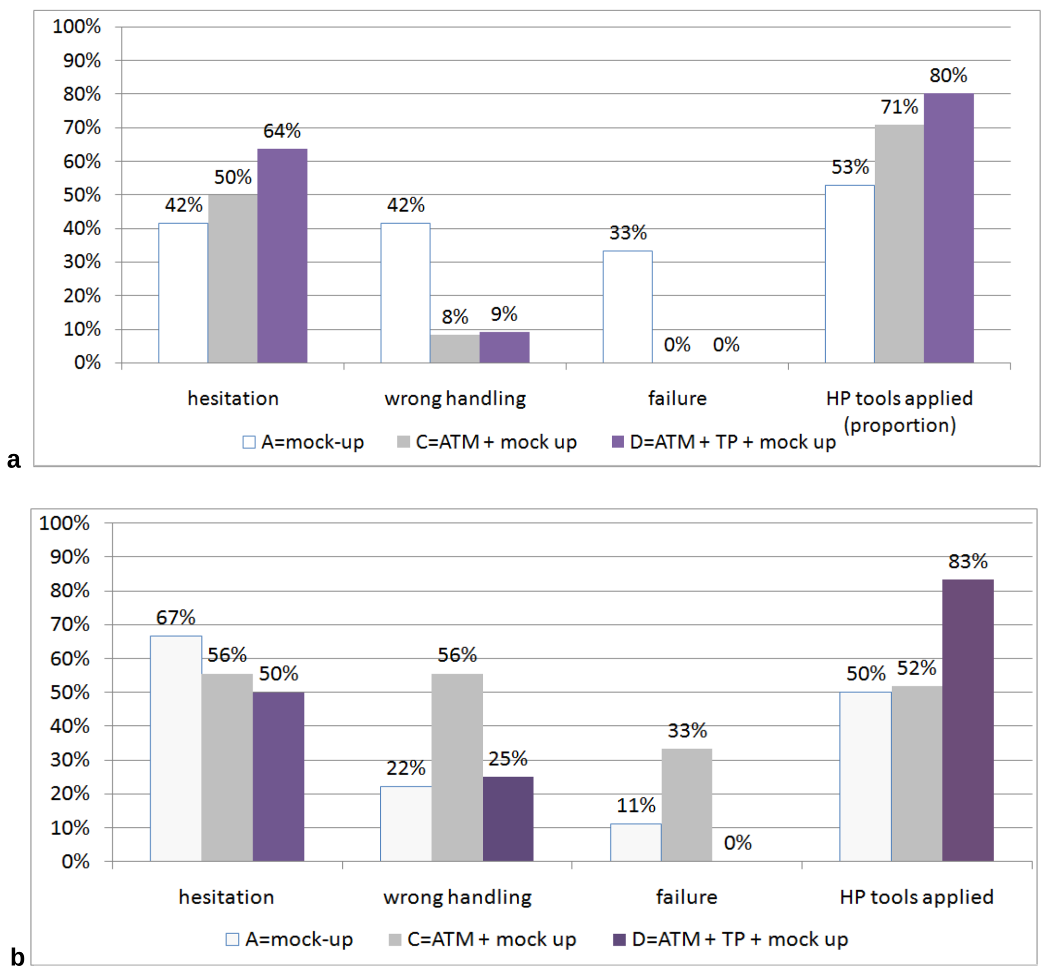

Fig. 3a & b. Comparison between results of a) the "experienced workers" and b) "novice workers" involved in three experimental conditions

4.1 Explaining Subjects' Performance

An a priori surprising result is that for condition A (control condition), the "novice workers" could be considered as presenting better performance than "experienced workers": HP tools applied were of the same level, and if hesitations were significantly better for "experienced workers" (42–67=–25%, $p<0.01$), incorrect handling and failures were significantly better for "novice workers" (resp. 22–42=–20% with $p<0.05$ and 11–33=–22% with $p<0.01$).

This finding may be explained by the SRK behavior model of Rasmussen [1,42-43] which 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" [1] (259), whilst "hypothetical explanation is formed and tested conceptually before action is taken", "related to the extend and quality of the [...] mental model" [43] (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.
- Rule-based behavior (R), when the subject "is familiar with the situation and only have few options for action at any given time" [43] (61), composing a sequence of actions "typically controlled by a [internal] stored rule or procedure which may have been derived empirically during previous occasions" [1] (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.
- 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" [1] (258), and applying "during familiar circumstances" when "sensory-motor routines take care of the direct control of integrated patterns of movements" [43] (61) without conscious control [1] (259). Routines are applied with a low degree of attentional control in highly familiar context.

Revisiting Rasmussen's model, these three main patterns may be considered inside a 2D-space in terms of attentional control given to the activity and familiarity with the activity (Fig. 4): Skill-based behavior is characterized by a low degree of attentional control and high degree of familiarity, 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 "experienced workers" had probably approached the task in condition A adopting the Skill-based behavior pattern: they

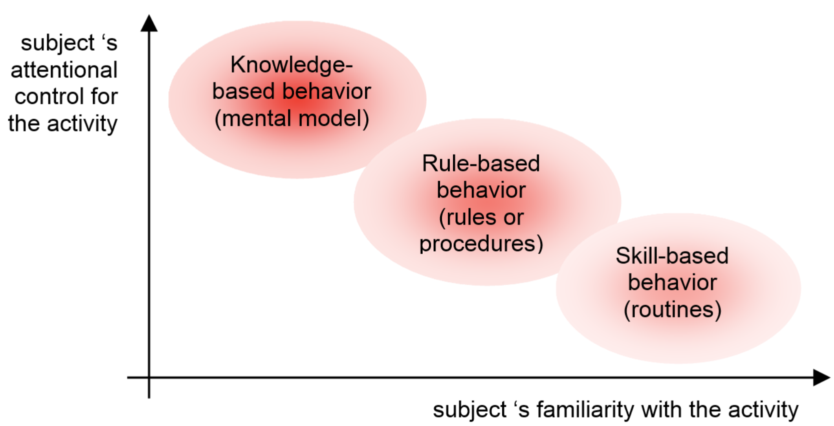

Fig. 4. Typical behaviors for a subject approaching an activity within a 2D model: Attentional control given by the subject to the activity vs subject's familiarity with the activity (Adapted from Rasmussen's SRK model [1,42-43])

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 (bottom right, Fig. 4). Conversely, the subjects of the “novice workers” had probably approached the task in condition A adopting the Knowledge-based behavior pattern as the situation was totally new for them (upper left, Fig. 4), analyzing the situation carefully, less sure in their acts (higher proportion of hesitations), less self-assured and acting probably more slowly.

The evolution of the criteria incorrect handling/ failures/HP tools applied for the “experienced workers” presented a significant continuous improvement slope from condition A to D. This suggested that:

- Working on virtual training improved incorrect handling, failures, and HP tools applied,
- Adding TP improved HP tools applied, not incorrect handling and not failures which already had an optimal score.

Hesitation increase could be due to “experienced” subjects' awareness growing from condition A to D by taking them out of the routine approach: condition A engaged them in a Skill-based behavior pattern, and conditions C and D made the subjects less likely to be caught up in their routines.

For the “novice workers”, the evolution of the incorrect handling/failures/HP tools applied criteria did not show a continuous improvement slope from condition A to D. Prior training without TP (condition C) clearly produced disturbance illustrated by performance results whereas it produced the opposite effect for the “experienced workers” who could summon remembrances of past experiences which could later be linked with the forthcoming task on device #1. Therefore, experienced subjects could proceed to a transference of what was done on device #3 to what they did on device #1, not the novice subjects.

4.2 Efficiency of the Debriefing

The global assessment of improvements considering incorrect handling/failures/HP tools applied gave between conditions C and D:

- About 11% performance increase in "experienced workers" for HP tools applied, none for incorrect handling and failures already close to lowest level (counterbalanced by hesitations)
- About 33% in "novice workers" (confirmed by hesitations).

The debriefing designed in the present study for transference process in a context of simulation training may thus produce a significant improvement in performance for experienced workers as well as for novice workers, with three times more for the latter compared with the former.

These findings are consistent with Kolb's well known model of [2-3] describing an efficient learning process as a four-stage experiential learning cycle (Fig. 5). It defines learning as “the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience” [3] (41) and it “portrays 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. According to the four-stage learning cycle, immediate or concrete experiences are the basis for observations and reflections. These reflections are assimilated and distilled into abstract concepts, from which new implications for action can be drawn. These implications can be actively tested and serve as guides in creating new experiences” [44] (333).

For condition A, subjects were asked to work on device #1, thus submitted to i”) a real operating situation (concrete experience without prior training). However, “experienced workers” could base their actions on past experience of similar working activities to be considered as active prior experimentations. In this case, for “novice workers”, ii) reflexive observation, iii) abstract contextualization and iv) active experimentation of the model did not apply.

Condition C transferred subjects from i’) a simulated situation (concrete experience) to i”) real operating situation (new concrete experience): Subjects were asked to work on device # 3 and then on device #1. As for condition A, "experienced workers" could base their actions on past experiences as active prior experimentations, suggesting a past active experimentation, but not for subjects of "novice workers" in condition C who only had a

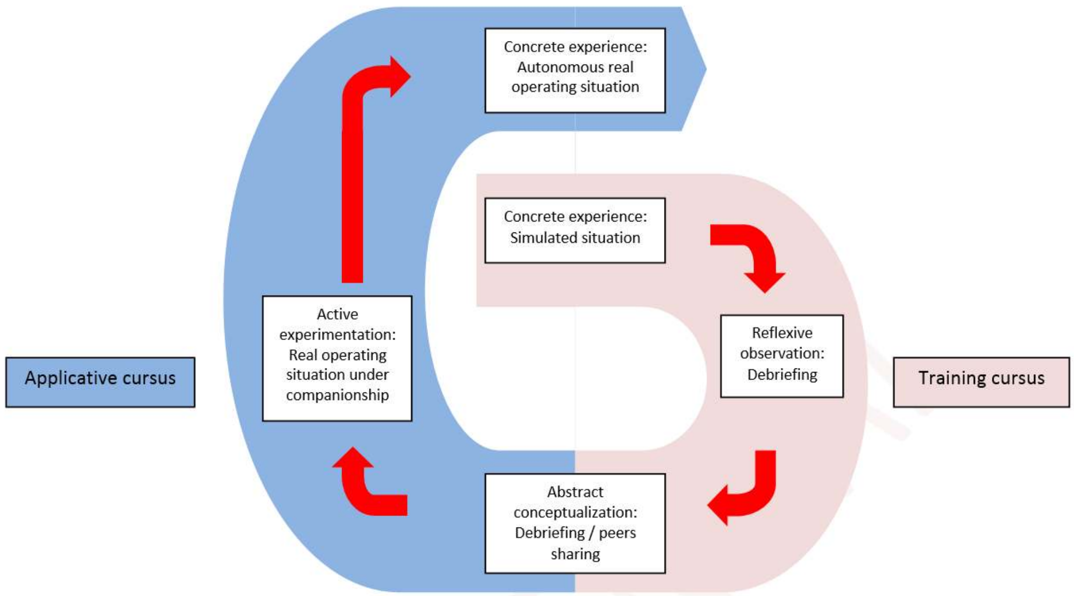

Fig. 5. Excursive cycle of the professional training process applying Kolb's model [2-3-44])

decontextualized experience (compared with the final task) on device #3. In this case, "novice" subjects were only concerned by dissociated concrete experiences.

Performance results obtained for "novice workers" in condition C hence highlighted the importance of the quality of each stage in the process described by the Kolb's model and the relationship between them: one stage missing led to lower performance. Furthermore, the fact that "experienced workers" could base their actions on past experiences in condition C whereas "novice workers" had just a prior decontextualized experience on device #3 (leading to dissociated stages) referred to the quality of the link between each stage of the cycle provided that this past experience could be assimilated to active experimentation.

We can observe that a large part of the efficient four-stage experiential learning cycle of Kolb's model was lessened in conditions A and C (some stages were missing, links between stages were of low quality level).

For condition D, the four stages of Kolb's cycle were of good quality, improving links between stages through the design of the debriefing. Therefore, in the light of the experiential cycle of Kolb's model, it was no surprise the best performance was obtained in condition D and worst in condition A.

5. CONCLUSION

The debriefing protocol 7S2P for simulation training, made up of seven steps (7S: reminder of ethics, trainees' expectations and goals, expression and discussion of trainees' feeling, reflexive analysis, comparative analysis with future situation, identification of additional needs, conclusion and summary) and applying two principles (2P: generation effect and projective perspective) have shown significant efficiency whilst performing a simple technical task: occupational training undertaken with two samples of subjects (experienced and novices) have proved that applying this protocol debriefing could enhance subjects' performance by up to 33%. Analysis highlighted how applying this protocol could compensate novices' lack of experience with their final performance being slightly less effective than the experienced subjects. The results have been successfully explained in the light of the revisited Rasmussen model [1] and Kolb's experiential learning model [2-3]. Debriefing helped experienced subjects to deal with their professional routines, and novices to compensate their lack of experience.

These results support the fact that decontextualized simulation training (such as Serious Games) may be of great benefit whereas, to date, simulation training gives too much importance to high fidelity simulation through full scale simulators.

Assess the potential of such debriefing protocol in occupational training centers and real operating conditions is now needed. Yet it cannot be immediate as it implies as a prerequisite the training of trainers to apply the protocol and to use special interview techniques.

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 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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