Human or avatar: psychological dimensions on full scope, hybrid, and virtual reality simulators

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Abstract

Professional training for risky professions involves simulation training. This kind of facilities has appeared very important to give to the workers the initial knowledge, to improve the skills of experienced workers, and to make them face rare situations for which they must be potentially ready to deal with.

The past years, a broad range of simulation systems including virtuality have become available on the market, and the professions concerned are wider every year. The possibilities for the training manager to skip from a full scale simulator to a virtual simulator is becoming very attractive because a virtual simulator seems to do the same as a full scale simulator and because purchase and maintenance are cheaper. But it only “seems” so. Shifting from the full scale to the virtual simulation gives advantages and at the same time leads to some major pedagogical differences which are not always thought about. These differences are mainly due to the subjective relationship between the trainee and the simulated situation, and thus, the simulator.

We here suggest some considerations about this subjective relationship by analyzing the psychological dimensions of the simulation.

We show how difficult it can be to train workers on simulators when embodiness and immersive conditions are not adapted, which imply to build a specific transference process in daily work activities after training sessions. Virtual simulators are more sensitive to this problem; we illustrate it with two important psychological processes encountered in risky professions: short term occupational stress and focusing structuration by the tools.

We conclude that virtual simulations and especially Serious Games can be chosen for professional training provided the professionalization strategy includes an adapted transference process of the know-how to develop the appropriate skills in non-simulated conditions.

1. Introduction

1.1. The context

It is well know now how simulators as training facilities can help risky professions concerning the management of high risk situations as the initial learning of technical acts, the compliance of actions or expected outcomes [1;2;3;4;5]. Their benefits have also been shown just when used as warm-up conditions [6].

Simulators are devices where workers can learn by doing mistakes without any consequence on the safety, the security, or the industrial production. Air force as airliners are in possession of a set of highly technological full scale simulators on pneumatic systems, Merchant navy as military navy have invested in elaborate full scale simulators for captain and pilot training, anesthetists as surgeons are nowadays trained on full scale simulators. These are only a few examples. As the aforementioned companies, Electricity of France knows how important training is to maintain the level of skills and know-how, or to train newcomers. For this aim, for over ten years, the company has set up training centers on each of the twenty French Nuclear Power Plants (NPP) including:

- a full scale piloting simulator (a full control room) for reactor pilots’ training (before, they were gathered in a few training centers),
- more recently, a full scale maintenance simulator (about 200 m^2 of ducts, valves, pumps, metrology…) to train plant field workers.

The financial investment is considerable. Furthermore, a project is in study in order to couple these simulators (piloting and maintenance), thus developing the possibility to train together maintenance workers or field workers with reactor pilots.

Nowadays, training for such professions has entered another dimension: virtuality. Instead of building costly full scale simulators (costly at the conception, for the maintenance, and for adaptation to new needs), the virtual training is rising in all countries for all industries, among which and more recently the Serious Games (SG).

SG are rising in training for at least two reasons which are absolutely disconnected. The first one is the progress in the computer technology giving every day greater possibilities for virtual and 2 or 3D development. The second one concerns the world of work and the recent changing in the professional training: the past years have been a time of understaffing for companies thus reducing the possibility of companionship and tutoring. At the same time and for the same reason (saving money) and to deal with the aforementioned problem, companies try to find cheaper, more efficient, and better adapted ways to train their staff. SG can be part of the solutions, at least for the big companies investing for a large number of people.

1.2. Definitions

But what is a Serious Game?

Almost all industrials know what and full scale simulators and virtual simulators are, but not Serious Games. Many managers say: "what is this? What do you mean? Never heard about that!"

Definitions have been suggested by several authors. Classifications have also been suggested by several authors. See for example Natkin's work [7], and see the original work suggested by Djaouti , Alvarez *and coll*. [8] based on studies of Propp [9] concerning Russian folk tales which had an influence upon European structural thought, both upon literary studies and semiology.

We shall not here enter in such a development which would be anyway a hard job and out of our purpose. To simplify the question, let us restrain the description to three main categories according to the utilization dimensions: informative (including advertising), training, gathering data, and a combination of several categories, as done in "Reveal by L'Oreal" [10]. This has given a specific nomenclature according to the use; for example, business game, edugame, datagame...

Among the three categories, the one we are interested in for this paper is training SG.

To suggest a definition of training SG, we shall first define full scale simulator and then virtual simulator.

The full scale simulator reproduces in scale 1 the real professional environment and is used to train people as close as possible to the real working situation.

The virtual simulator reproduces on a computer the real professional environment and can be seen on the screen as close as possible to what could be seen of the real working situation through a camera. In this scope, even the operator may become virtual as an avatar.

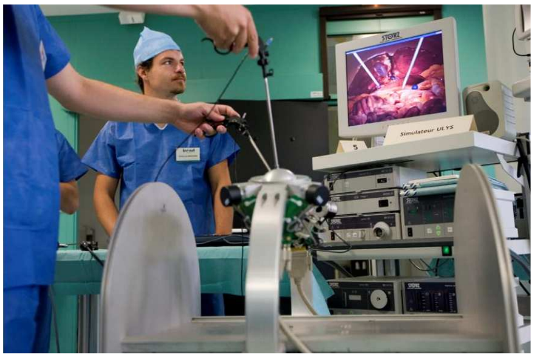


Figure 1: Hybrid simulator ULIS for surgeon training [11] combining virtual scenes inside a patient on the computer screen and real surgery tools with force feedback.

The hybrid simulator combines both images of the real world and virtual images. Several types exist. It can be implemented on a computer where the user works with real and virtual images which are superimposed together to suggest on the screen a simulated situation for training purposes (fig.1). It can be a full scale simulator in which some parts are replaced by large screens reproducing virtually environments like console components (fig. 2), equipment of the process or the surrounding world (it is the case of the Air France simulators for aircraft pilots).

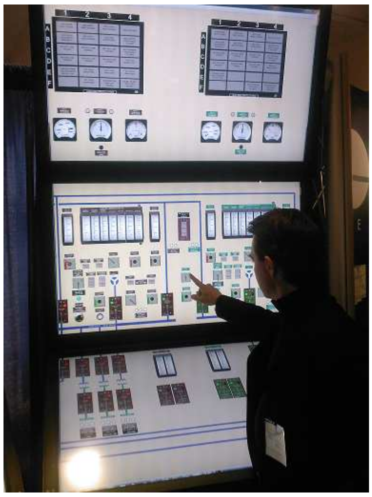


Figure 2: Hybrid simulator developed by GSE Systems for nuclear reactor control rooms: the three boards are scale 1 ontouch screens and all components are virtual.

within this scope, the SG belong to virtual simulation family: an environment for the user is reproduced virtually on the computer screen which can represent a real environment, and the user can be represented as an avatar (called pedagogical agent in case of training simulator) inside the virtual world. The difference with the virtual simulation lies in the "G" of the "SG" for "game", referring to the "ludus" conceptualized to define SG by Alvarez et al. [12]. The SG will not circumscribe the pedagogical actions to the obvious training purpose. For the given pedagogical purpose, it will include a playing dimension and will try most of the time to suggest another context in order to improve skills. According to Le Marc et al. [13], "Serious Game is a branch of video game. Serious Games include an educational scenario with educational objectives for the players. This kind of game aims to allow the player to learn during the game."

We can thus suggest the definition for training SG :

The training Serious Game is a training software including a playful dimension offering users the typical game latitude within a set of rules and targeting specific pedagogical goals.

This definition agrees with the "G/P/S model" suggested by Alvarez et al. [12].

1.3. The aim of the study

The purpose of this paper is to expose a comparative analysis of the advantages and drawbacks between classical full scale training simulators and a virtual training simulator (among which the Serious Games for training) from the psychological standpoint, used for high risk socio-technical systems. In other words, when managers want to train their staff and need to choose for training between full scale simulator or virtual simulator, they must know what they will gain and what they will lose. Furthermore, knowing what they lose, how to compensate this loss?

These questions are of great interest because this comparison must help to elaborate better training simulation facilities (whatever their nature: full scale or virtual) with regards to the pedagogical goals in a context of potential shift from the full scale to the virtual simulator. Yet, the question has not been studied as suggested here. If analyses are numerous concerning psychological dimensions of training, they have been conducted independently for each kind of facility (full scale simulator, virtual training) but not considered together. Analysis devoted to pedagogy (see the collective work in the book of Pastre, [14] for example; and see papers like Rogalski et al., [15]) can apply to training as a generic concept; numerous productions concern full scale simulators (see the collective work in the book of Fauquet-Alekhine & Pehuet, [16], for example; and see papers like Yee *et al*., [17]; Müller *et al*., [18]; Fauquet-Alekhine *et al*., [19]) and the number of papers for virtual training is wide too (see for example [4;20;21]; see the ten years review of Mikropoulos et al., [22]).

We shall here use a part of the work already done by other scientists in their respective fields in complement of our specific observations, interviews and tests, to suggest a comparative analysis of classical full scale training simulators and virtual training simulators. A special focus will be done for training SG.

2. Material and methods

At this stage, we must give a theoretical complement concerning a common confusion done between "non-simulated" and "real", induced by the common opposition made between "simulated" and "real". A simulated work activity is the situation involving trainees on a simulator. A non-simulated work activity concerns operating, piloting, intervening in a situation within a non-simulated context inducing real consequences on security, safety and production. This situation is called by many "real situation" or "real life" as opposed to "simulated situation". But speaking like that is a mistake: a simulated situation is obviously part of the real life (the false life does not exist), is a real situation, and being trained on a simulator is a real work activity, and of course a different activity from the non-simulated one. In parallel, the opposite of "real situation" or "real life" are "false situation" or "false life" which do not exist, or, at least, cannot describe the simulated situation. This is why we shall most of the time use "simulated" and "non-simulated". The term "real" can nevertheless be used: concerning the simulator, according to us, it is right to designate the simulator as the "non-real" process system or "simulated/virtual" process system opposed to the "real" system. This closes the theoretical complement.

The method is based on observations, interviews, tests and analysis.

Observations concern simulated and non-simulated work activities.

Non-simulated situation observations have been conducted with nuclear reactor pilots and aircraft pilots. The aim was to understand the non-simulated work activity to appreciate what is the need in terms of training.

Simulated situation observations have been done with nuclear reactor pilots, aircraft pilots, anesthetists, surgeons, harbor pilots. The aim was to analyze what is done for training compared to the need, and to analyze weaknesses and strengths.

Interviews have been done with trainers and trainees concerned by nuclear reactor pilots, aircraft pilots, flight fighters, anesthetists, surgeons, harbor pilots, race car pilots, and fire fighters. The aim was to validate observations, improve analysis and get more information about their feelings.

The simulation facilities involved full scale simulators, virtual simulators and hybrid simulators.

In order to emphasize specific points, tests have been developed and applied: they concern the focalized attention, the perception of stress. For this last point, physiological measurements have been done. The aim was to have a better understanding of the trainees' feelings.

All this material has been analyzed with the help of studies done by others and available in the scientific literature.

3. Results, analysis and discussion

First of all, we must point out the shared factor for all training means we are concerned with: full scale simulators as hybrid or virtual simulators aim at offering trainees a full immersive environment through space (full scale) or screen(s) (virtual).

This basic condition implies to discuss and compare the immersive conditions, the embodiness of the work activity, the effect of an avatar and, as these means are developed for risky industries or professions, some psychological dimensions must be discussed, as stress and other effects.

3.1 Immersive conditions and immersive distance

According to our observations, the first point to be highlighted and analyzed is the capacity for a simulator to give trainees some full immersive conditions: one of the most important characteristics of a simulator appears to be able to make trainees feel like they are living a non-simulated situation. According to trainers as to trainees, whatever their profession, the more the simulated situation is close to the non-simulated one, and the better it is. The immersive distance must be as short as possible. Unconsciously or not, this wish appears to be linked to the skills acquired on the simulator and the transference process which will follow when working within the real socio-technical system: the more simulated and non-simulated contexts are similar, and the easier the skills acquired on simulator will be available in the daily work. Interviews concerning the trainees' feelings after a poor immersive simulation session perception show that, furthermore, the trainees feel it difficult to be involved in a simulated situation when they do not have a similar perception of the activity compared to the non-simulated situation.

Thus, they are not ready to learn during the training session, and the pedagogical goal cannot be reached. All kinds of simulators are concerned by this immersive problem: from this standpoint, full scale as virtual or hybrid simulators encounter the same difficulties at a more or less important level. The full scale simulator is concerned through the Human-Machine Interface (HMI) and the virtual simulator is concerned trough the Human-Software Interface (HSI). Usually, the difficulty is lessened by the trainer at the beginning of the training session if s/he makes an appropriate introduction [16]: the trainer explains that a simulator is a training facility that allows to reproduce a part of the reality; variability is obviously weaker and this will be an advantage to reach the pedagogical goal even if the simulated situation takes some distance with the non-simulated one.

Yet we must think about the (un)capacity of a training simulator to be an efficient immersive situation as a multi-factor context: variability is not the only parameter that might compromise the immersive quality of the training. Another important parameter is the ability of the training session to lead the trainees in their zone of proximal development as introduced by Vigotski [23] and discussed by others (see for example [24;16]). We shall develop this point further.

3.2. Embobiness

The second point of importance to be analyzed is the capacity of the simulator to let/make the trainee embody the work activity.

As we shall explain, this process is different from one trainee to another and is linked with the experience of the subject.

But first, let us clarify the "embodying the work activity" concept, what we shall refer to later by the substantive "embodiness". Concerning the professional practices, it is well known now that knowledge usually acquired during the initial training period can only be transformed into skills by action in work situations. Here, action in work situation is the application of the knowledge to perform a task. The subject involves himself in the activity to apply what he knows and what he thinks to be able to do, and thus improves the knowledge which has already become or will soon become a know-how. This transformation makes him elaborate his own professional style, inside a professional genre concerning the trade [25;26;27;28]. This transformation process is not only a subject's action on the system, because the relationship is bilateral: the system acts on the subject and transforms him; the subject learns how to feel the system. For example, the field worker comes to a pump and verifies the way it turns by putting his hand in front of the rotor of the engine to feel the air flow, or puts his hand on the ventilator to feel the vibrations. The car pilot ears the engine. The nuclear pilot ears the click of the counter when injecting fluid in the cooling system. The echograph puts his arm in a specific position on the patient's body to move the probe… All these "details" make the worker become a professional and help him to be efficient. This state of the art, embodied by the worker, elaborates its own style inside the professional genre. Both are sometimes so strongly constituted that adapting them (even through training sessions) can be very difficult [29].

Then the question is: how will the simulator be able to elaborate the embodiness of trainees? Will it be the expected one (what is needed for the non-simulated situation, for the real system), something close to the expected one which will have to be adapted after through a transference process, or will it be something absolutely different? For instance, what kind of embodiness might develop physician-trainers on surgery simulators when a mistake leads to a final issue which is the patient's death? As pointed out by Soler & Marescaux [30], through a trial/failure training process on a virtual training device which easily allows to repeat an undesirable issue (the patient's death), it might make the trainee unconsciously accept, through training and failure repetitions, that "death" is linked to and solved by "replay".

Another example concerns the echograph training on a low cost hybrid simulator [31]. To train future echographs, the classical simulator gives a part of a plastic body where the physician will displace the probe. In order to broadcast the training, low cost solutions have been studied among which the plastic body is replaced by a piece of foam. The result, in terms of perception, is assumed to be quite different for an experimented trainee and a neophyte: while putting his arm on the foam, the experimented trainee will re-summon some known feelings of past experiences while the neophyte cannot, as he does not have any background. When this feedback is available, it helps the simulation training to be more effective for the trainee. But the embodiness built for the neophyte will be slightly different, and the trainers will have to take it into account for the future transference process in the non-simulated situation. An interview with a French nuclear reactor pilot gives arguments in this way: trained on full scale simulator for about twenty years, he said that according to him, a virtual environment training could fit pilots only if they are experimented, because a newcomer would not be able to feel the control room without being inside. This highlighted difference is similar when considering teenagers hearing music on their ipod or on their mobile phone in the subway: if the sound is loud enough for you to hear it, the quality of the sound is very bad for you who do not know the music and have never heard it before. It is quite different for the teenager: he does not hear what you hear but a re-composition of what is heard with what was heard before at home with much better acoustic conditions.

Thus, embodying the work activity needs a direct physical contact with the real system or something that makes the trainee feel like in contact with the real system. Furthermore, primary embodiness on simulator, transformed when living the non-simulated activities, is quite different from the following embodiness situations on simulator: this is due to the possibility of re-summoning the feeling of the non-simulated situation inside the simulated situation. In other words, the daily work life gives feelings to the workers that help them live a simulated situation where the implicit (the non simulated details) is compensated by remembrances.

It must be clear now that virtual training simulators (among which SG are the furthest from the real system) do not give the same embodiness as full scale simulators. The potential embodiness deviation must be carefully considered by the trainers, and pedagogical actions must be included in a complementary transference process.

3.3. Examples of difficulties for immersion and embodiness

3.3.1. The case of a specific feeling: stress

To explore further the question of embodiness, let us consider a factor which is common to all professions concerned by training sessions on simulators: stress. Stress is common to all these professions: if the companies invest in expensive simulators, it is because the work activity is risky for workers as for the people more or less linked to the workers (patients of the surgeon, passengers of the aircraft pilot, people living around the NPP for the reactor pilot…). So, all professionals trained on simulators are concerned by occupational stress. Recent studies [19] have shown that, in some conditions, trainees could be put in such conditions during the simulation sessions that they could be concerned by cognitive disorder reducing their ability to learn. First, it was shown that for short term occupational stress as encountered on simulated situations, performance versus stress matched an inverted U curve as suggested very early by Yerkes & Dodson [32]; then, measurements were done for anesthetist training on full scale simulator in stressful conditions and the results showed that most trainees were in a cognitive disorder state during training, thus likely unable to learn correctly what was taught.

These experiments were conducted using specific factors of stress, as explained thereafter in 3.3.1.a & b.

3.3.1.a Stress in test conditions

In order to demonstrate the relationship between performance and stress, subjects were individually put into a working context inside which several factors were intentionally stressful [19]. Among them, a clepsydra was used to make a time constraint in a very specific manner, specially developed for the purpose. The clepsydra presented three holes in the upper part of its bottom receptacle and the subject was expected to finish the task before the water would flow out of the holes on his desk while the experiment was conducted inside the subject's work office. Analysis has shown that this factor was highly stressful. It was used for subjects in stressful conditions, but not for the non stressful conditions subjects.

It has been demonstrated [19] that a relevant characterization of stress could be done by a reduced coefficient of stress designed using the mean and max heart rate (HR_{mean} and HR_{max}) as follows:

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

where $$HR_{max\ ampl} = HR_{max} - HR_{mean}$$

giving the following performance vs stress curve for a healthy middle-age population as presented in figure 3.

The determination coefficient of a polynomial fitted curve is $R^2 = 0.69$. Besides, by calculating the standard deviation of the normalized data deviation projected to the longitudinal axis of the data cluster (here the X-axis) defined as:

$$FA_x = \left\{\frac{1}{N}\sum_i [Y_i - \bar{Y}_i]^2\right\}^{1/2}$$

where $Y_i = y_i^* - 1$ and $\bar{Y}_i$: fitted value related to x_i

we obtain $FA_x \cong 12\%$ which is the demonstration of a good consistency of the data, with an obvious position on the right side for the subjects concerned by cognitive disorder during execution of the task.

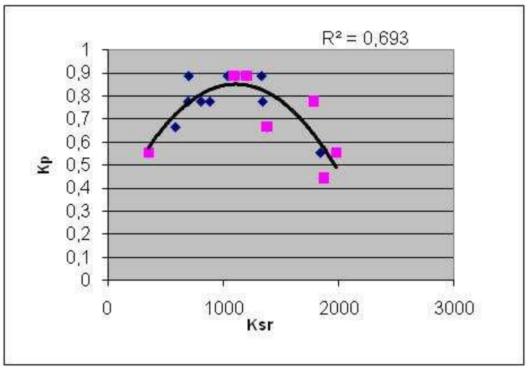


Figure 3 : performance coefficient K_p plotted vs reduced stress coefficient K_{sr} discriminates the No Stress Conditions (dark diamonds) and the Stress Conditions (clear scare) for the Stress-test' subjects.

How might virtual simulation generate such a stress? Among all the stressful parameters, the clepsydra has been selected by the subjects as the most stressful: the subjects heard the noise of the water flowing, and they thought that it would finally flow on the desk.

3.3.1.b Stress in simulation training conditions

Application of this performance vs stress rating was done for anesthetist training performed on a full scale simulator [19]. During the simulated situation which took place in a surgery theatre, healthy middle aged students used real injections on a computerized plastic mannequin, and read information about the patient's clinical state from a monitoring device which made sounds like in a non-simulated situation. On the one hand, there were sounds, and on the other hand, the specific smell of products. These sensorial parameters obviously affected the immersive conditions of the students, making the situation closer to the one encountered in the anesthetist's daily professional life.

The performance vs stress curve obtained for this experiment subjects showed that most trainees discovered the simulator and thus were not used to this training context, encountering the cognitive disorder zone of the Yerkes & Dodson curve [32] on figure 4.

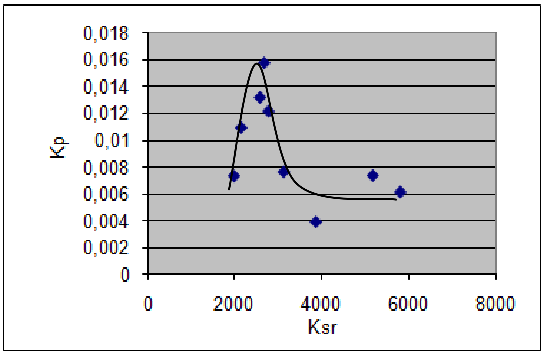


Figure 4: performance coefficient versus reduced stress coefficient for anesthetist residents not submitted to strong physical efforts.

Calculation gives $FA_x \cong 16\%$ illustrating an acceptable representativeness of the data.

How could virtual simulation generate such an effect due to stress induced by the situation with all its sensorial components, including noises and smell?

These two examples are given to illustrate some limits of the virtual training compared to the full scale simulation.

Furthermore, even when stress is generated by virtual simulation, we do not have the same stress as in the non-simulated situation.

Interviews with a French Merchant Navy trainer points out that the observed stress seems to be the same in non-simulated and simulated situations. But in fact this similarity only concerns the symptoms. If the resulting action is considered, what is done by the stressed trainee on simulator is not the same as what is done by the same stressed person in a non-simulated situation, and depends on the source of stress: on simulator, the trainee is stressed because of the evaluation (source), and he will lead the ship close to the edge very slowly (resulting action), while in the real harbor, the subject will be stressed because of the workload and the number of vessels waiting to enter the harbor (source). He will then lead the ship close to the edge much faster (resulting action). We have obtained similar observations for aircraft pilots, nuclear pilots, and anesthetists.

This difference is due to the stress type induced by the situation. To characterize stress, (macro) variables can be used as a concept to designate the stress factors. According to the second theory proposed by Karasek & Theorell [33], these (macro)variables can be distributed among three dimensions describing stress: the request or job demand dimension including the context, the subject's autonomy or decision control, and the subject's social support perception. Other models distribute these variables among three different dimensions: the subject's vulnerability, the context, and the stress factors [34], or over six dimensions: demand, control, support, relationship, role, change [35].

Yet, in mathematics, the dimension of a space or object is informally defined as the minimum number of coordinates needed to specify each point within it. In a 3-D space, a point is fully defined by a set of 3 coordinates, and every objet is fully defined by a set of coordinates or a set of equations referring to the 3 dimensions. This is possible only if the dimensions are independent from one another.

According to us, as in mathematics, an adequate model of the stress phenomenon must be based on independent dimensions.

Our own observations show that:

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

The conclusion is that the appropriate dimensions are:

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

But our aforementioned observations show that these three dimensions are not sufficient to fully describe the stress phenomenon; as a matter of fact, we must admit that this 3-D model only describes the source of stress. In the interactional approach, stress is a result of the interaction of the three dimensions which produce consequences that themselves describe stress by what we call "symptoms" [19]. Symptoms are consequences of specific stimuli; they are responses of the subject to these stimuli. We shall gather here subjective and physiological consequences as "symptoms" (including "signs", while the strict meaning of "symptom" would only concern the subjective consequences, the objective ones being designated by "signs"). Symptoms may be physiological, psychological. As an extension, we can also speak of behavioral symptoms.

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

Concerning behavioral symptoms, interviews with a French Merchant Navy trainer (reported above), as well as observations for aircraft pilots, nuclear pilots, and anesthetists, pointed out that the observed stress seems to be the same in non-simulated and simulated situations.

But only through the symptoms. The resulting action was quite different. It shows that the behavioral symptoms must be taken into account to define stress.

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

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

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

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

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

In each 3-D space (fig. 5), stress is defined by variables on each axis which determines a volume of stress. The first volume finds its consistency through the interactions between the three dimensions (context – demand – subject's characteristics), and produces the consistency of the symptoms volume in the second 3-D space (psychological – physiological – behavioral). These three dimensions interact together as psychological symptoms usually produce physiological responses, both making possible or not such behaviors. And the two spaces interact together, as symptoms produce a feedback on the source.

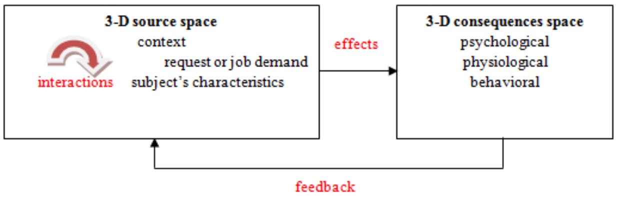


Figure 5: the two 3-D spaces model for short term occupational stress.

Considering these facts, what can we think of the stress induced by a full scale simulator compared to the one induced by a virtual simulation? If we accept that stress can be described by three characteristics which are the source, the consequences (symptoms, and resulting actions), and the type of stress (physical or mental, short or long term; see Fauquet-Alekhine et al., [19]), then we claim that they will be different because of the source of stress and because of the fundamental difference of the immersive capacity of each one: the full scale simulator puts the mind and the body inside a simulated situation while the virtual environment of the SG puts the mind inside the simulated situation, and the body only through the mind inside the simulated situation. The distances between the subject and the work system are quite different.

3.3.2. The case of focusing by the tools

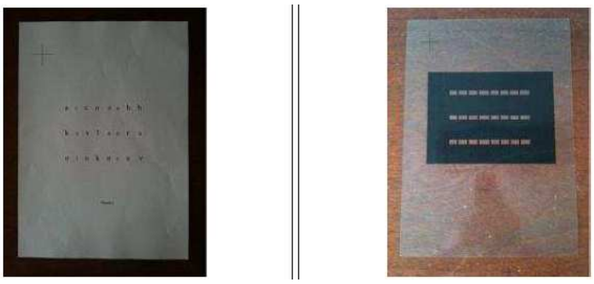
In order to illustrate another difference related to the immersive conditions between a full scale simulator and a virtual simulation, we shall expose the case of the structuration effect of the tools on the activity. The aim is to show how this effect is necessarily lived differently on each training device, and how one of them is obviously farther from the non-simulated situation than the other.
The structuration effect of the tools designates the mental process by which the subject will be led to actions and results specifically due to the tool used for the activity. This can lead to unacceptable situations.
The tool designates a mean that makes interface between the subject (the one who plans the action of transformation) and the object (what will be transformed according to the subject's will). It lays down the relationship: subject-tool-object where tool is a mediator. It can be a physical object that extends the subject to transform the environment (e.g. carpenter's hammer); it can be a method that helps the subject to transform the social world, the organization, the attitude, the behavior (e.g. the surgeon's protocole) which can anyway be materialized as a physical tool by being written on paper (e.g. the professor's books for teaching).
Investigating the structuration effect of the tools, and developing training of workers for them to be sensitive to this process is important from the safety standpoint because it can help to avoid unacceptable situations.
To illustrate the structuration effect of the tools, we suggest two examples.
The first one concerns an event encountered on full scale simulator in a training center for French operators managing complex industrial systems.
An operator in the control room detects a defect on a required piece of equipment. After confirmation of the defect, he must refer to the prescription book (i.e. a physical tool) to know what he has to do in case of this defect precisely. To read this physical tool, he will apply a routine tool: the way he is used to reading the prescription book. He reads the section entitled "events" and does not look at the section entitled "generality" in which, unfortunately, a particular prescription is given. Some of the factors that make the pilot do like that are:

- his own perception of his knowledge of the prescription book,
- his experience of this way using the prescription book, validated by the absence of problems when doing so,
- the thickness and weight of the prescription book (more than 470 plastic pages),
- the complexity of the prescription book.

In practice, a fast way to know what he has to do in case of technical problem is to first open the section "events". This is much faster than what must be done theoretically: opening first the section "generality", reading it and interpreting it, and finally checking what is written in the section "events". Yet, the right way to do is this one. According to the principle of cognitive economy (we could say: from the "principle of least action" borrowed from Physics), opening at once the section "events" is efficient, but from the safety standpoint, there can be some risks. For this example, the risk exists indeed: the pilot applies partially the prescription since in this case of equipment defect, it is useful to read the section "generality", because specificities may be described in order to be applied.
Observations and discussions then lead to the fact that the physical tool, by its physical characteristics, makes the operator manipulate the prescription book in a specific way, and thus develop a specific routine tool.
Further observations and discussions show that if the prescription book is used in its available version on a personal computer, the result is the same, but the main factor leading to this result is the complexity of the prescription book.
In practice, the prescription book is used by the workers in its paper version, not in its computer version, because it is heavy to enter the documentation data base and because workers feel more comfortable with paper.
This example shows that the full scale simulator is able to offer a situation where the relationship between the tool and the subject will be similar to the non-simulated situation (relation with the paper book), on the contrary of the virtual simulation.

The second example of structuration effect of the tools concerns a research experiment planed on a French industrial plant (more than 1000 employees). Subjects (N=70) have been asked to perform individually a simple task consisting in counting the number of letters for which the size was less than 5 mm height on 5 boards, each one presenting 3 lines of letters (fig. 6a). To do the task, the subjects were suggested to choose between two physical tools: a ruler or a mask presenting opened windows (fig. 6b); the windows were said by the researcher as calibrated in height at 5 mm. The tools here are of physical types: the mask and the ruler. Boards were analyzed one by one. The task was asked to be performed as fast as possible with a chronometer put in front of the subjects. Subjects were chosen so that every profession was represented, from operational and tertiary

departments. A specific additional sample of subjects was gathering students (9-14 yo).
The aim of the experiment was to identify who could treat and see that the last board had 9 letters per line while all the others had 8 letters per line. Of course, the mask had 8 windows per line.



Figures 6a & 6b : letter-boards and mask used for the test relative to the structuration effect of the tools.

The main results were:

- most of the subjects chose the mask (more than 89% of *N*=60),
- some subjects perceived the mask not confident,
- all the subjects who treated the last letters were not conscious of that,
- only 11% of the subjects treated the last letter (the ones who had chosen the ruler), these 11% divided in two groups: the industrial workers among which 6% treated the last letter, and the students among which 30% treated the last letter.

Observing what was done by each subject was remarkable and concerns directly our topic:

- Some subjects choosing the mask made some prior tests (manipulating mask and ruler) and decided to use only the middle line of windows which was the only one confident according to them; applying the mask on the boards to check the first and third lines, one could see a shift between the board and the mask (but in fact they did not) at the bottom or the top of the board respectively (fig. 7a, b & c).

Figure 7a, b & c: Examples of shifting of the mask when using only the middle line.

- Some subjects choosing the mask decided to apply the mask on the board according to the right column of letters rather than to the right side of the mask support; doing so on the last board, the mask support was shifted from the board but no one saw it.
- One subject had a doubt about the sizing of the last letter of the first line of the last board by the mask; the subject took out the mask and measured the letter with the ruler, so measured a C (9th letter), replaced the mask, watched a B (8th letter), and did not notice the difference.

In this example, it appears obviously that the focusing due to the tools and the structuration process take different forms depending on the subjects and the way they manipulate the tools and boards: there is a pregnant place of the possibilities offered to the subject concerning the way tools and boards are held in the hands, put in front of the eyes, and the way it could deconstruct the focusing structuration of the tools.
This experiment has been done to better understand the process of focusing structuration effect of the tools during the work activity as described in the first example. The training to avoid this process has helped to adapt pedagogical goals on full scale simulator.
It appears clearly that to be worked efficiently, the cognitive process must be known, understood, and integrated in the training with a HMI of a full scale simulator rather than with a virtual simulator HIS.

This does not mean that the process of structuration effect of the tools cannot be worked on virtual simulators: virtual simulators will suggest a different context, thus for a different cognitive process and cognitive bias. Therefore, adaptation to the non-simulated situation will have to be elaborated within the perspective of transference of know-how. This emphasizes that another form of the process can be worked on such simulators and that the work will be farther from the reality than the full scale simulator.

3.4. Pedagogical agent and avatar
Several studies are available in the literature concerning the analysis of effects (among them this aforementioned distance) produced by a pedagogical agent, called “avatar” in case of this agent representing the subject (see for example [36] Beale & Creed; [37] Veletsianos). Veletsianos demonstrated the obvious necessary congruence to be found between the pedagogical agent’s appearance and the content area under investigation. But this appears to be just a replication of what can be observed in daily life when people (especially in French culture) do not recognize someone’s skills on the pretext that s/he does not look like he would have to according to their own references [38;39]. According to the results obtained by Maldonado et al. [40] quoted in [38], HSI is usually perceived more positively by the trainee if it contains a more expressive agent and, in these conditions, it can reduce frustration more easily [41] especially if it is a female agent [42]. Maldonado et al. [40] also found that subjects that interacted with such expressive agent performed better on a test than those who interacted with an unemotional agent. Yet, Beale & Creed [38] 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 [43], quoted in [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. But anyway, whatever the subjects’ gender, most of them preferred interacting with an empathetic device ([44] quoted in [38]).
The distance between the subject and the pedagogical agent can be reduced when the agent is an avatar, representing the subject inside the HSI system. [45] quoted in [38], found that the subjects represented by expressive avatar felt more involved in the task compared to a non-expressive avatar.

Yet, Beale & Creed [38] warn about these aforementioned results, concluding that generalities were difficult to be confirmed as results depended also on the task suggested, which could induce specific positive/negative feelings for the subjects.
Nevertheless, our own investigations match most of these results: the more expressive the pedagogical agent is, and the more efficient it is for immersive conditions and performance of the tasks. It is the same when the pedagogical agent is psychologically closer to the subject (case of an avatar). To illustrate these proposals, we shall expose two examples: a teenager game player, and a firefighter. We shall then extend these considerations to another role which could be played by a pedagogical agent beyond the training on simulator: the debriefing of the simulation training session.

3.4.a. The teenager game player
Interview has been conducted with a 14 y.o. French teenager playing games on PC and console DS. All the games played by the boy are of fantasy war type (see table 1 listing the games played by the teenager and involving an avatar).

Table 1 : games with avatar played by the teenager

Games	**Computer system**
Sacred	PC
Persian Wars	PC
Star Wars (lego)	PC
Dragon Quest IX	DS
Narnia'world I	DS
Narnia'world II	DS
Caribbean Pirates	DS
The golden compass	DS
Combat de géants-Dragons	DS

In this list, "Star Wars" and "Combat de géants-Dragons" are interesting because of their specificities. The first one was played by the teenager when he was a child; this game is made for ypung children and the design as the possibilities of the game are not sophisticated. For the teenager, it is clearly a game he does not use anymore: not interesting because too simple. The second one concerns a game in which humanoid characters are absent; the world of the game is only inhabited by dragons and thus the suggested avatar is a dragon. When the teenager is asked to find another game with humanoid avatar which presents the same quality in terms of design and possibilities of the game, he chooses "Caribbean Pirates". When he is asked to compare avatars of the two games and to explain what he prefers and why, at once he claims to prefer the human avatar. He does not know why he prefers this one, and suggests that it is more practical, perhaps because he can more easily manage the possibilities of the avatar as closer to his own body. This first element (to prefer the human avatar probably because closer to his own body) confirms the necessity for the avatar to be close to the subject playing as shown in [45].
When the teenager is asked about what he prefers between a game with avatar and a game without (for the same quality in terms of design and possibilities of the game according to him), his answer is definitely "with". He explains that, according to the game rules, the avatar gives the possibility to take power and freedom in the game, which is less the case when he plays without avatar but as a leader of a team for example. What is thus interesting in the game is the possibility to gain faster in power, which helps the subject through the avatar to be less constrained by the rules and have more freedom in the world of the game remaining the conclusions of Beale & Creed [38].
The teenager is asked whether the avatar's capacities can be chosen and composed by the player. He answers that it is the case only in one of his games, "Dragon Quest IX", and that it is very important for him to have such a possibility: again, he feels more free to elaborate an avatar closer to what he wants to be according to the goals of the game.
This second element (to elaborate an avatar closer to what he wants to be) confirms the necessity for the avatar to be close to the subject playing. This reminds the results of Maldonado et al. [40].
Moreover, the aforementioned freedom feeling appears to be of great importance in a game, and as we shall see after, also in a SG or any virtual environment.
The teenager is then asked to compare the feeling when playing and when watching a movie: in which case does he feel more "inside" the story? According to him, "it is quite different", the descriptions he gives show that the immersive conditions are much better in a game with avatar than in a film, and especially in a game like "Dragon Quest IX" because you can compose both the avatar and the fight: in the other games, you press a button and the avatar engages the fight according to the software which plans the details of the fight, while in "Dragon quest IX", you compose the fight step by step which makes you feel much more involved in the story. As you manage the fight, as you decide each avatar's movement, you feel yourself closer to the avatar and thus more inside the story.
This third element (to decide each avatar's movement and thus be more inside the story) confirms the necessity for the avatar to be close to the subject playing and emphasizes the necessity of the perceived autonomy to be effective.

3.4.b. The firefighter
A French firefighter officer explained during an interview he has been trained for several years on the virtual platform gathering a ten of computers for officers to learn fire crisis management. In such a context, nothing is real: all the resources the officers have to manage (men and equipment) are seen on the computer screens. Some of the officers are represented inside the fire fighting scenario by an avatar in the case of a commandment in the field, and others play their own position in the head quarter of the simulation platform.
The officer during the interview said that it helps him to have a better representation of where he is in the field and how he can interact with other people. But there are a lot of things which cannot be felt while are of great importance in the real field: the weight of the individual equipment, the warmness, the dust and the smoke making it difficult to breathe. All these stress factors change the man's capacities for the decision making in action; it means that the virtual simulator includes a great bias. Nevertheless, according to the officer, the virtual

simulator is a relevant tool to learn and be trained for crisis management, but is not a Serious Game according to him. He is also used to working on RescueSim and on SecondLife for the crisis management training; he said these look like Serious Games: "you have an avatar, you choose how you want your avatar, you can put your own face on the avatar through the webcam, you can choose your firefighter uniform with a high level of details; it is very good to do so: you can really recognize people and what they are doing in the game, and it helps you to play inside the game. It is very interesting to play in such an environment".
The danger would be to think that all can be learned just on the simulator and thus to forget the necessary transference process in the real activity.

These two examples show how much the avatar can help the player or the trainee to have better immersive conditions inside the virtual world. It also shows that subjective dimensions linking a videogame player or a virtual simulator trainee to the HIS can be similar.

3.4.c. Avatar and debriefing

These considerations lead to another question: could the debriefing of a team simulation training session be done through avatars? Even if this has not been observed according to our own experience and to the available literature, the possibility of doing so has nevertheless been suggested by some of our co-workers: if we are able to elaborate team simulation training with SG, it means we could train a team while people stay in their office without gathering in the place; then, we can imagine people in different towns or even different countries, trained together and involved after the simulated situation in a collective debriefing of the training session. But to do so, trainees can be involved in a video-conference, or in a kind of virtual environment on a computer where each trainee is represented by its own avatar. What could be then the implications?

To answer this question, we must first explain the importance of the collective debriefing session. Through the simulated situation experimented, trainees work in the zone of proximal development [23], but the psychological process remains incomplete if the subjects are not asked to put their activity into words, which makes them think their activity afterwards. This is the aim of the debriefing session. This stage produces development, creation and construction [46]. Avoiding this opportunity corresponds to thinking that what can be seen through the behavior is reflecting the dynamics of the subjective world which is not exactly true as discussed for example by Alexandrov [47] and analyzed in several studies (see for example [48]): as it may correspond from one subject to another to very different neural activities, behaviors and attitudes during a given activity have to be put into collective discussion by the actors. This will proceed of the individual as of the collective know-how and skills [49;50;51], improving individual professional style and collective professional genre [16;25;26;27]. Nevertheless, to be efficient, the exchange in the team must be authentic. If trainees are playing a role trough the avatar during the debriefing, referring to the previous examples, we can assume at least one advantage and one drawback. The advantage might be the freedom to say what would not be said in a face-to-face collective discussion, because of shame for example, authority gradient, fear of an aggressive colleague's direct reaction. The drawback might be to give one's agreement for some ways of working that would never take place in the future working situation.

We thus define at least three natures of immersion in simulation training: i) direct immersion of the mind and direct immersion of the body, ii) direct immersion of the mind and immersion of the body through the mind with an authentic relationship to others, iii) direct immersion of the mind and immersion of the body through the mind with an avatar relationship to others.

3.7. Special focus on training SG

After all what has been presented and discussed above, using training SG puts at once emphasis on the question of the distance and psychological nature of immersion.

Concerning immersive conditions, embodiness, capacity of a SG to make the trainee feel what could be felt in non-simulated situations according to the five senses (hearing, touch, smell, sight, taste), the training SG has two drawbacks which are intrinsic constituents: the distance due to the computer, and the playful dimension. This playful dimension puts at once the distance between the simulated and the non-simulated situations. Nevertheless, if the sensorial system cannot be fully stimulated, senses which are stimulated are stimulated at a higher level.

In their conclusions, Le Marc et al. [13] pointed out the broad range of the video games possibilities in which sensorial system can be quickly stimulated by the software, and the easiness with which the program can suggest different level of difficulties (beginner, intermediate, expert). Huang et al. [24] highlights the exciting aspect of virtual reality learning environment which trigger imagination. The interface between the subject and the environment, if well thought and correctly elaborated, can lead the trainee to faster improvement not only because of the pedagogical content of the software, but also because of the pleasure it gives to the subject. Here, we must not think anymore in terms of Human-Machine Interface (HMI) but in terms of Human-Software Interface (HSI). Thus, we can say that virtual simulators can transform the immersive conditions drawback into a benefit, what cannot offer full scale simulators. This gives SG an actual advantage compared to full scale simulator.

As we have seen above, embodiness is closely linked to the distance between the subject and the simulated situation. In both cases of the full scale simulator and ten SG with an avatar, the distance between the subject's mind and the simulated situation could be thought a priori the same, as the main actor (the subject and resp. the avatar) are inside the situation. But in fact not, because of the body: in the first case, mind and body are inside the simulated situation, while in the second one, the body is in the situation through a pedagogical agent which obviously has an influence on the way the subject's mind is involved inside the situation.

What makes the SG more attractive, the freedom, also makes the distance subject-situation grow. But paradoxically, it does not seem to increase the distance between the subject and the situation: the immersion is effective. Just it changes the nature of the immersion. "Games induce players to express themselves and to invent from the rules" [13]. Creation, freedom, and inventive thoughts and actions because of freedom, have been widely observed in virtual training situations. Huang et al. [24] speak of the way it triggers the subject's imagination. But when by Soler & Marescaux [11;30] point out that repeating an undesirable issue (the patient's death) during surgery training can lead to the undesirable result that the trainee will learn unconsciously that "death" is linked with and solved by "replay", it illustrates the nature of the distance. In this case, the patient is not any more a patient to stay alive, even if the trainee is completely involved in the simulated situation in order to succeed. Interviews with people playing with the on-line game "Second Life" show the same phenomena: the immersive conditions of the subject inside the game are often fulfilled, but the freedom left on the one hand by the rules, and on the other hand by the possibility for the subject to hide himself behind the avatar, make the player allowing him to do things he would never do in real life.

But paradoxically, the playful dimension that puts at once the immersive distance appears to be an advantage compared to the training virtual simulator which would aim to be as close as possible to the non-simulated situation.

The immersive distance allows the SG to take full advantage of its playful dimension which is straight off legitimate by the distance: as the simulated situation is said at once far from the non-simulated situation, the trainee will not expect a short immersive distance and will be ready to be trained differently. This leads to the decontextualization possibility of the SG which can be seen as a strength for learning but implies a complement within the following process of transference. Moreover, as said by Weckel & Besse [52] the interest of a decontextualization permits a non-drama situation concerning the trainees' choices and errors.

We must not we see SG like a simulator but as the natural complement of a simulator, as suggested by Mavre [53].

4. Further discussion and Conclusions

4.1 Further discussion

All the previous developments concern high risk socio-technical systems. Let us have a short look to another field: business. If virtual environments and SG are used for playing, learning, training, they are also used to recruit. For example, L'Oreal group is used to developing SG on line in order to invite candidates and make a selection. The first one was developed in 1992, Brandstorm. Several came after: Challenge (for management), Ingenius Contest (for chartered engineers), Innovation Lab, and in 2010, claimed as definitely innovative: "Reveal by L'Oréal" (http://www.reveal-thegame.com/). The player fills up his profile, travels from one place to another, from one character to another with a lot of interactions (quiz, enigmas). This reveals the applicants' skills and helps them to discover the firm culture. At the end of the game, the player may be invited to apply as future employee of the company [10].

L'Oreal claims one million applicants in 2008, and about 1.2 million in 2009. Of course, this number is given with an uncertainty induced by the "multi-applying" (when one player decides to register a false name in the aim to test the game, and be more successful with another trial with his real name).

This method permits a broad selection of candidates, but can it replace the job done by a recruitment agency? The answer is 'no'. Proof is that psychologists of a recruitment staff explain that, despite all the tests and interviews which can be done with a candidate, the best way to know if s/he will fit the job is to let her/him do the job. Many examples show that some applicants were chosen as suitable for a job and failed in the situation, and vice-versa.

Again, it is shown that business games can make a part of the work, but not all.

4.2 Concluding remarks

It must be first reminded that a lot of drawbacks concerning the full scale simulator will also affect the virtual simulator (including the SG): the main point is the gap between the simulated and non-simulated situations; if this gap is too large, or if it is not correctly managed by the trainers, the trainees cannot be immerged inside the simulated situation and perceive it as the real working situation. For this aim, i.d. an effective immersion of the subject inside the simulated situation, the trainers must carefully build the pedagogical goals for good immersive conditions. These cannot be pedagogical intentions, as suggested by some authors [8;13]. It must be at once considered and perceived as real and effective goals, thought and elaborated as goals to be reached, and the training session as the SG must be developed in this perspective.

One important advantage of virtual environment and SG is the possibilities in which sensorial system can be stimulated by the software, in which it triggers the subject's imagination at the condition of a satisfactory Human-Software Interface (HIS).

This interface must be elaborated according to the embodiness expected for the trainee according to the profession, taking into account what can be done in parallel for his professional training in terms of transference process: skills on a simulator are not skills for non-simulated situations; an adaptation is required.

Embodiness of the profession leads to the question of the avatar suitability for training. It is shown that the more expressive the pedagogical agent or the avatar is, and the more efficient it is for immersive conditions and performance of the tasks. It is the same when the pedagogical agent or avatar is closer to the subject by what he can be and what he can do under the subject's control. Yet, this point remains not investigated concerning the debriefing: could the debriefing of a team simulation training session be done through avatars? It

could be interesting to do a comparative study between a face-to-face debriefing and an "avatarized" debriefing? What would we lose and what would we gain through the shift "face-to-face" → "avartarization"?
These considerations lead to define at least three natures of immersion: i) direct immersion of the mind and direct immersion of the body, ii) direct immersion of the mind and immersion of the body through the mind with an authentic relationship to others, iii) direct immersion of the mind and immersion of the body through the mind with an avatar relationship to others.

Yet, improving Human-Software Interface and the whole virtual environment can lead to lose the reality. This leads the trainers and conceivers to be warned about the risk of training people for the simulator rather than for the non-simulated situation, the real process.

And beside all those socio-psychological considerations and correlated implications mainly concerning immersive conditions and embodiness, another aspect of the virtual simulation must be considered from a psychological standpoint: the psychosomatic effects called "cybersickness" (not discussed in this paper). This psychological dimension can be a drawback to reach pedagogical goals and to build suitable immersive conditions.

The advises to deal with the aforementioned difficulties can be summarized shortly:

- The introduction by the trainer to the trainees of a training session is fundamental; if there is no trainer (like for SG), the software must take into account this point. The introduction is of high contribution to build good immersive conditions.
- The training simulator (full scale, virtual, SG type...) must not be thought as a whole but as a part of a pedagogical program including the adapted transference stage for the skills acquired during training to be adjusted to the non-simulated situation.

The main problems of SG are perfectly described and illustrated by the psychological and philosophical dimensions of "The Matrix", a 1999 science fiction-action film written and directed by Larry and Andy Wachowski [54]. The story is based on the inventive concept of a world led by intelligent machines which use alive human bodies as energy source. For this aim, humans are maintained in kinds of cocoons were they are fed; the bio-energy is thus used. In order to keep humans efficient and to get from them better production, machines give them through a sophisticated neuro-connection a mental activity by putting their mind inside the Matrix. It is a virtual human world representing the earth context of 1999 while the real world is 2199. Inside the Matrix (which can be seen as a huge SG), humans interact through avatars. For the Matrix to work correctly, everything is kept in order by softwares injected inside the virtual world like "agents". The Matrix is so powerful that when the mind perceives something, the body fully feels it: who perceives to die really dies. The story points out questions concerning several major and interesting points in the philosophical, sociological and psychological fields (see for example [55]).
The problem of the machines' reign is that some humans have discovered a way to disconnect themselves from the Matrix and to come back to the real world to become rebels. Doing so, they are able to use their understanding of the Matrix's nature to bend the simulation's laws of physics, giving themselves superhuman abilities within the virtual world. And the problem of some rebels is to prefer the virtual world of the Matrix than the real one: they thus betray their species.
Just let us have a look to a sample, a scene involving Mr. Cypher Reagan, escaped from the Matrix nine years ago, and Mr. Smith, a software agent (fig. 8)

Figure 8: Cypher Reagan, in The Matrix movie, watching a virtual piece of meat by the mean of his avatar, and feeling it.

-Do we have a deal, Mr. Reagan?
-You know... I know this steak doesn't exist. I know that when I put it in my mouth, the Matrix is telling my brain that it is juicy, and delicious. After nine years, you know what I realize? ... Ignorance is bliss.
-Then we have a deal.
-...I don't want to remember nothing. Nothing. You understand?...And I want to be rich. You know, someone important. Like an actor.
-Whatever you want, Mr. Reagan.
-Okay.

This scene emphasizes:

- The risk of a so perfect SG that virtuality might be considered as a better world worth to live in than the real world.
- The correlated risk of the subject's desire to prefer living inside the virtual world and the potential cleft between the subject and the society leading to a social alienation, according to the psychology conceptualization.

The progresses in computer industry make nowadays more and more probable this kind of issue. Considering this question concerning training, it reminds the example of Soler & Marescaux [11;30].

For a company like EDF, the SG could be applied for crisis management training, as made for firemen in many countries for example, involved in fire protection training on a virtual reality simulator (fig. 9). For example, the Forest Fire simulator at SDIS 13 -

Departmental School for Firemen in Velaux-Marseille, France (see Vidal *et al*., [21;56]), gathers several professions on the same place managing virtual equipment and teams.

Figure 9: Two trainees at work on the Forest Fire simulator at SDIS 13 - Departmental School for Firemen in Velaux-Marseille, France.

This simulator permits to work on various functions such as managers, Helicopter Water bomber pilots, or operators at the Departmental Operations Center for Fire and Rescue (CODIS). Each is in radio contact in an area equipped with a flight simulator, or driving simulator, with maps. Advanced equipment which gives a high degree of realism to exercises and avoids mobilizing in the field whole teams and heavy equipment. Financial benefit is substantial to the point where EDF might be interested in these methods with a view to developing training simulators for the crisis management linked to nuclear accidents. At the present time, four exercises a year are done (involving tens of persons), one of which concerns authorities (involving hundreds of persons), and this for the whole nuclear fleet, namely nineteen nuclear plants.
From a financial standpoint, savings are potentially considerable.

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