Serious Games & Simulation for Risks Management

Proceedings of the Serious Games & Simulation for Risks Management Workshop
Published under the direction of Philippe FAUQUET-ALEKHINE and Luc SOLER (Editors)

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Observatoire de Paris – France

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For risky professions, learning possibilities are limited by the own nature of the subject. Simulation tools and Serious Games are a mean of major enhancement for behavioral or situational trainings.
Is it the same for all risky activities? The workshop tried to answer this question by presenting a state of the art and practical examples.

Beyond this understanding, the workshop aimed to facilitate exchanges between all the actors and to position men within the world of these new tools.

ARMIR

Collège de Polytechnique

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Séminaire Serious Games et Simulation pour la gestion des risques

Le 05 Décembre 2012
A l'Observatoire de Paris
77 avenue Denfert Rochereau

Comité d'organisation

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Christophe FRERSON, officier de sapeurs-pompiers, spécialiste en gestion de crise

Marc LABRUCHERIE, expert en facteurs humains, ancien commandant de bord

Julian ALVAREZ, chercheur au LUTIN, laboratoire spécialiste des serious game

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Bertrand WECKEL, directeur, ATRISc, officier de sapeurs-pompiers, spécialiste en fiabilité et gestion de crise

Dans les métiers à risque, les possibilités d'apprentissage sont limitées par la nature même du sujet. Les outils de simulation et les serious games représentent un progrès majeur pour des formations comportementales ou situationnelles.
En est-il de même pour les domaines à risque ?
Telle est la question à laquelle ce colloque se propose d'apporter de réponses en présentant un état de l'art et des cas concrets.

Outre cette compréhension, le colloque a pour objectif de contribuer aux échanges entre tous les acteurs et de repositionner l'homme face à ces nouveaux outils.

ARMIR

Collège de Polytechnique

Actes du séminaire Serious Games & Simulation
Publiés sous la direction de FAUQUET-ALEKHINE Philippe et SOLER Luc

Serious Games & Simulation

for Risks Management

The Chairman's letter

Ce colloque avait pour ambition de confronter plusieurs expériences sur la formation à des situations à risques et ceci dans des métiers différents.

Près de 50 personnes sont venus assister et contribuer à cet échange. Les expériences appartenaient à des domaines forts différents : la chirurgie, le nucléaire, la sécurité civile, l'aéronautique. Mais toutes faisaient émerger des problématiques communes : la gestion de l'imprévu, le stress, ...Et chacun d'évoquer avec toute la modestie des scientifiques, comment il abordait ces problématiques et les pistes de solutions.

Les échanges étaient forts, sans langue de bois, avec plus de questionnement que de réponses, car nous sommes au début de la recherche et du développement de ce domaine. C'est en ce sens que ce colloque fut aussi une réussite, car il a démontré son utilité et sa pertinence et ouvre la voie à de futures rencontres dans le même esprit.

Nous tenons à remercier tous ceux qui ont contribué à la réussite de cette opération, membres du comité de pilotage, organisateurs, intervenants.

Michel ROCHET
Vice-Président du
Collège Polytechnique
de Paris, France
Chairman du Workshop

This symposium aimed to confront several experiments on training in risk situations and this in various professions.

Nearly 50 people came to attend and contribute to this exchange. Experiences belonged to different major fields: surgery, nuclear industry, civil security, aeronautics. But all did common issues emerging: the management of the unexpected, the stress management,... And each discussed with the the scientists' modesty how s/he approached these issues and the possible solutions.

Exchanges were strong and sincere, with more questions than answers because we are at the beginning of the research and development of this area. It is in this sense that this workshop was also a success, because it has demonstrated its usefulness and relevance and it has opened the way to future meetings in the same perspective.

We thank all those who contributed to the success of this operation, members of the steering Committee, organizers, and interveners.

Michel ROCHET
Deputy-President of
the Collège Polytechnique
de Paris, France
Workshop Chairman

Serious Games & Simulation for Risks Management

The Scientific committee President’s letter

Using games to learn has been well known for a long time. For instance, one of Aristotle’s most renowned quotes was “one has to play in order to be serious”. He mentioned here tragedy and comedy, where an actor plays a defined role. Aristotle also indicates that no tragedy or comedy can be efficient without real immersion of actors and audience that can be obtained through the visual apparatus of the play, including set, costumes and prop. Such an immersion can today be obtained efficiently in virtual simulation. Used for education, such a simulator can also become a serious game. A Serious game is a software used to provide an educative or marketing message through a gameplay. Simulations and serious games are today more and more used for education in major companies. First of all, the game play of serious games is clearly more attractive. Moreover, virtual simulation and serious games are less expensive in comparison with real simulation where users have to reproduce a real situation during a real exercise. For instance a fire extinction in a training building reproducing a real building is replaced by a virtual one. Finally, virtual simulation and serious games are highly efficient to reproduce risky situations without real risks for the user or the real environment. Risk reproduction, analysis and education are thus really challenges that simulation and serious games can encounter as it will be developed in the following articles.

Prof. Luc SOLER
Scientific committee President
IRCAD
Strasbourg University
(France)

The Scientific Committee :

Executive summary

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An introduction to Serious game

Definitions and concepts

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

Abstract

This article proposes a definition of the object "Serious Game" and an approach dedicated to classify its various occurrences.

1. Introduction

Serious Game application fields are related nowadays to many sectors such as health, defence, education, policy, training and ecology, and keep on expanding. Serious Game therefore addresses a set of markets. This positioning is thus accompanied of a very rich typology to refer to the object: *Educational games, Simulation, Alternative Purpose games, Edutainment, Digital Game-Based Learning, Immersive Learning Simulations, Social Impact Games, Persuasive Games, Games for Good, Synthetic Learning Environments, Games with an Agenda*… This census reflects the numerous actors with an interest in the Serious Game and the diversity of their approaches.

Despite this diversity of names, several contemporary definitions of Serious Game are proposed. The more general seems to be that the game designers Sande Chen & David Michael: "games whose first purpose was not mere entertainment." At the same time, Professor Michael Zyda, currently Director of the USC GamePipe Los Angeles laboratory, proposed a more specific definition: "*A mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives.*"

In these definitions, we find a common base with the vision of the Serious Game put forward by Benjamin Sawyer: "[…] *developers, researchers and industrial people, who are looking at ways to use video games and video games technologies outside entertainment* ». As a consultant, Sawyer is one of the important figures of this sector in the United States. He notably founded in 2002 "The Serious Game Initiative", an independent institution to develop Serious Game and its industry. However, some actors do not proceed as well. For example, in the sector of vocational training, some are based on role games or board games rather than video games. Kevin Corti perfectly illustrated through a very critical article that calls for the expansion of the usual definitions of Serious Game. He also recalled that some of the actors, sometimes quoted to illustrate the Serious Game, do not recognize it in this term, and prefer other names such as Game-Based Learning and Simulation. This claim refers us to the "Serious Game" of Clark Abt's book published in 1970. In his writings, this researcher sees the games support allowing to enrich the school curriculum by reducing the border between "school learning" and "informal learning". He supports his thesis by many practical examples of teaching by the game for topics ranging from physics to human sciences, through the policy. Although that inspired by the first computer simulations, Abt offers at the time a definition of the term "Serious Game" which is not restricted to the only video game (computer game). In the 1970s, a "Serious Game" could be a computer game, a game, a role-playing game or even a game of outdoor.

Today, this link with computer support appears to be a constant in the Serious Game industry. Nevertheless, professionals do not unite around a same definition of the object.

2. A proposal for a definition

Aware that there are a multitude of different approaches to the Serious Game, we know that to register in one of them implies limits. However, to move forward in our words, we must position us. Thus, in this article, we choose to relate us to the definition of the Serious Game, developed during our previous work: "*computer application, for which the original intention is to combine with consistency, both serious (Serious) aspects such as non-exhaustive and non-exclusive, teaching, learning, communication, or the information, with playful springs from the video game (Game)." Such an* *association, which operates by implementing an utility script, which, in computer terms is to implement a package (sound and graphics), a history and the same rules, is therefore intended to depart from the simple entertainment."*

This definition can be summarized by implementing the following relationship:

Serious Game = Utilitarian function(s) + Video Game

3. Difference between Serious game and video game: notion of Serious Gaming

Nothing prevents to play a video game originally dedicated to the only entertainment in adopting a posture of "serious". Many examples can be identified in the education sector as we are including Gee (2003) or Schaffer (2006). In France, the Pedagame collective performs field experiments on the use of video games from entertainment to educational purposes. For example, the set of karaoke Singstar PS3 (SCE London Studio, 2008) is used as support of course to work the pronunciation of the English to college students. In another register, the "question-answer" game Buzz! Quiz TV (Relentless Software, 2008) was hijacked by teachers of history and geography to current discussed concepts. They rely, to do this, on the possibility of create custom questions proposed by this title. Ludus network brings together teachers using the set (video or not) for educational purposes, highlights also the use of Sim City (Maxis, 1989) Lords of the Realms II (Impressions Games, 1996) for the history and geography.

Nevertheless, a fundamental difference persists between this type of approach and the Serious Game as defined above. If the result appears similar (a game used for serious purposes), only the Serious Game was explicitly designed for this use. This approach is thus distinguished from the idea to take a commercial video game to assign it a new function posteriori. This argument is logically put forward by the Serious game industry to enhance their expertise. This tends to exclude the approaches of diversion from the Serious games field. If this issue remains controversial, an interesting concept was suggested by Henry Jenkins through the term "Serious Gaming". Thus, in considering the difference in design between the titles "diverted" and the other process, we propose to reserve the term "Serious Game" for games that have explicitly intended for purposes other than simple entertainment by their designer. "Diversion video game" approaches, which allow a game to serve serious purposes not anticipated by their designer, are included in the term "Serious Gaming". This term includes then any use of a game for purposes other than simple entertainment, whatever is the original intention of its designer.

4. Classify Serious games

Facing the very rich typology of Serious Games identified : News Games, Advergames, Military Games, Exergames, Edugames, Datagames, etc…, it seems relevant to clarify this aspect, by putting in place a classificatory system. In our work, we have retained the three following criteria:

• **G: Gameplay**, based on the gameplay of the "Serious Game". This test provides information on the playful dimension by providing information on the type of playful structure used.

• **P: Purpose**, based on the purpose of the "Serious Game". This test provides information on the functions beyond the "simple entertainment" desired by the designer.

• **S: Sector**, based on the areas of applications covered by the "Serious Game". This test informs on the type of public market (market, age…) that the designer seeks to achieve.

These three criteria form the "G/P/S model". This is a guide that allows to classify the "Serious Games" at the time by their playful dimension (Gameplay), and their serious dimension (allows of & sector). It is implemented effectively on the website:

http://serious.gameclassification.com

4.1 "Gameplay" criterion

Introduced by Caillois in 1958, and then updated by Frasca in 2003, the concept of "paidia" and "ludus" refers to two distinct playful forms. Their difference is on the construction of the playful structure. For example, Sim City (Maxis, 1989) appears to take the "paidia", because it proposes no objectives explicit to allow the player to "win". According to the definitions proposed by Salen & Zimmerman, Sim City is indeed a game devoid of "quantifiable outcome", a final State terminating part while offering an assessment of the performance of the player. This means that Sim City is a video toy.
Conversely, a game like Pac - man (Namco, 1980) "ludus" defines explicit goals (eat all the dots while avoiding the ghosts) that are used to assess the performance of the player, a positive return (points score gain) or negative (loss of a life). We have, in this case, to a video game.

To illustrate, by analogy, the difference between "video toy" and "video game", take a doll Barbie (Ruth Handler,

1959) and the Monopoly game (Charles Darrow, 1935). The Barbie doll is a toy because no record is provided in the box to tell us what rules to follow and how to win. It's here to play, therefore, paidia. A video toy offers a similar approach. In the case of the Monopoly, there are rules to follow to win. This is underlying objective: destroy all of his opponents. It is here ludus. This is exactly what underlies a video game.

Note that the difference between "paidia" and "ludus" is equivalent to that found between "play" and "game" in the English language. The "play" is close to the idea of fun (Barbie) then that the "game" behind the notion of rules of game (Monopoly).

Based on this principle, we refer to "Serious Play", serious games are based on a structure "paidia" (toy video) and "Serious Game" those that are based on a structure "ludus" (video game).

4.2 “Purpose” criterion

The assessment of the objectives that a designer wants to aim through the realization of a "Serious Game" is far from simple. Usually, different designations such as Advergames, Edugames, Exergames, Datagames, News games, Edumarket games, Health games, Military games, etc. are used to distinguish the "service categories" of the Serious Game. In our opinion, the use of these categories is not necessarily more relevant because the criteria are devoid of formal criteria. We have therefore tried to establish a more synthetic list of categories.

Among the categories generally used to describe the purpose of a Serious Game, we find "Edugames" (and its equivalents "Games for Education" and "Learning Games") or "Advergames" (and its equivalent "Advert Games"). In a simple manner, a "Edugame" allows an educational message. An "advergaming" to promote a product or service, that can be interpreted as a deliberately positive message about transmission of said product or service. Somehow, although their intention is different (commercial or educational), these two categories of Serious Games appear to have the purpose of a "message". A similar observation can be conducted on other usual categories: the "Newsgames" broadcast an informative message, the "Political Games" a political message, etc....

In the end, the different categories of "purpose" generally used are apparently used to differentiate the nature of the message broadcast by the "Serious Games". By classifying messages by their nature, then we identify them as follows:

-The informative message, to broadcast a neutral point of view.

-The educational message, to transmit knowledge or education.

-The persuasive message, to influence.

-The subjective message, to broadcast an opinion.

However, all Serious games do not have the purpose of a message. Indeed, we have games belonging to the categories "Training and Simulation Games" or "Games for Health" aimed another purpose: provide training.

For example, Pulse! is used to train emergency physicians to handle crisis situations, while MoSBE (Breakaway, 2007) allows to prepare soldiers for military operations. The concept of training here results in the development of physical or cognitive skills on the practice of the game.

A third and less common purpose seems also interesting to identify to classify the "Serious Games" to us: games designed to facilitate the exchange of data. In this registry, we have for example Google Image Labeler (Google, 2007). This Serious Game was developed by the company Google in order to improve the relevance of its image search engine. Each played match is thus a means to enrich its database, collect statistical data to refine the links between certain images and lists of words associated with... This type of application, called "Datagame", is still relatively little widespread to this day.

In summary, we therefore propose to classify the purposes according to three main categories:

-Broadcasting a message: the Serious Game is designed to deliver one or more messages. They can be of four different natures: educational (ex: Edugames), informative (ex: Newsgames), persuasive (ex: Advergames) and subjective (ex: activist games, Art games). A same game can combine several types of message.

-Providing training: the Serious Game is designed to improve cognitive or physical Player capabilities (ex: Exergames)

-Promoting the sharing of data: the Serious Game intends to facilitate the exchange of data (ex: Datagames) between players, or the Publisher of the game and players.

4.3 “Sector” criterion

This criterion offers two levels of information.

First of all, information on the application domain within the Serious Game. This list of areas of application must regularly be updated to reflect the emergence of new sectors. It has, today, the following areas: State & Government, Military, Health, Education, business, Religion, Art & Culture, Ecology, Politics, Humanitarian & charitable, Media, Advertising, Scientific Research.

Other information concerning the target audience which is transcribed by age as well as by type: Public, Professionals, Students. For example, for the field of Health, practitioners will be considered as "Professionals", medical students as "Students", and patients as "General Public". This information can, of course, be more detailed as required, for example in seeking to identify the age, sex, nationality, etc. of the target public.

5. Synthesis

5.1 Definitions

This article has led us to define the 3 following concepts:

-A Serious Game is characterized by two main points:

(1) It combines video game and one or several utility functions: broadcasting a message, providing training, facilitating the exchange of data.

(2) It targets a market other than the only entertainment: defence, training, education, health, commerce, communication...

-A Serious Play is part of an approach similar to the Serious Game but relies on the video toy instead of the video game: it thus does suggest explicit playful objectives to do in order to "win" or "lose".

-The Serious Gaming is characterized by two main points:

(1) The action "to associate", without computer programming, and posterior with a videogame objective one or several utility functions: broadcasting a message, providing training, facilitating the exchange of data.

(2) This action is then within a context of use which departs from the only entertainment: defense, training, education, health, commerce, communication...

5.2 Classification

To understand the diversity of the Serious Game, it is important to classify both by its playful dimension and its utility dimension. For this, we propose a classification system called the "G/P/S":

-"G", as "Gameplay", determines if the Serious Game is based on a video Game or a video Toy. A Video Game sets rules that evaluate the performance of the player unlike Toy that fits more in the idea of a sandpit where is fun and where the notion of "win" does not exist. In the case of a "Toy" type, we speak of "Serious Play" instead of "Serious Game".

-"P", as « Purpose », put in place the main function of the Serious Game. This test indicates if Serious Game is used to broadcast a message, provide training, collect data, or more of these functions at a time.

-"S", as "Sector", identifies the Serious Game markets. Thus such applications may apply to defense, education, health...

These three combined criteria allow to reflect the "Playful" dimension (Gameplay) and the "Serious" dimension (Purpose + Sector) by the designer of a "Serious Game". However, players can use a video game in a way that has not necessarily provided by its designer. It is then "hijacking a use", which allows for example to use for Serious purposes a game basically designed for the entertainment. These two approaches, original design and use hijacking, constitute the whole of the "Serious Gaming".

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Virtual Surgical Simulation
Major rules to develop an efficient educative system

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Abstract

Education of interventional radiological or surgical gestures is currently essentially performed on mannequin, animals and patients. However, several virtual simulators have been developed in order to propose a new educational approach. Our work aims at seeing how such simulators can efficiently replace current educational approaches by taking clinical routine constraints into account. Two simulators have been developed and evaluated in order to describe their benefits. This work allowed us to define 4 simulator exploitation rules, in particular in autonomous mode. It also clearly shows the feasibility of such a training at the first training step. It finally shows an unexpected result: it improves student consideration of medical orientations which have difficulties in attracting the young generation, such as radiology or surgery.

1. Introduction

Minimally invasive operative techniques are one of the major surgical progresses. They greatly reduce the hospital stay and the postoperative morbidity of patients. However these techniques are complex to realize and to educate, gestures being totally different from standard open surgery. Current education is then essentially done on human mannequins, animals and finally, and most frequently, on patients. Indeed, practical teaching of gestures is done during surgical interventions on patients, which means for teachers that it does not require additional hours only dedicated to education.

This usual education based on companionship has several drawbacks. When it is done on mannequin or animal, evaluation remains globally subjective. Moreover, the anatomy of such models remains different from real patients. Finally, pathologies, which are the surgical target, are not developed on animal models. To overcome these limits, several surgical simulations have been developed. The first version was based on mannequin using a box in which objects were inserted that had to be manipulated with the real instruments of minimally invasive surgery. These "endo-trainers" were progressively perfected and led to real human dummies featuring plastic organs that could bleed (e.g. Simulab corporation, Limbs&Things). The main drawback of these training systems is the high cost of artificial organs that have to be replaced after each training session, while the realism remains very questionable compared to a real patient. Maximal realism is obtained when operating animals, as in the greatest training centres such as IRCAD (Institut de Recherche contre les Cancers de l'Appareil Digestif). One of the drawbacks of that kind of training, just like the endo-trainer, remains the subjective aspect of evaluation, the quantifiable data resulting from such training being very limited. Furthermore, simulated pathologies are not present in the animal. Finally, the anatomy of the porcine model, though similar to human anatomy, is not identical. It is however currently the best training method, the closest to reality since the living animal is set up under general anaesthesia in the same conditions as a patient.

Unlike these "real" simulations, virtual simulation provides multiple quantifiable and exploitable data in order to objectively evaluate students. Over the last 5 years, many virtual surgical simulators have thus been developed including simulation scenarios under thematic modules. Literature is full of validations showing the benefit that those virtual simulators can provide [1-7]. They allow to learn basic gestures in minimally invasive surgery in a step by step mode, leading in the end to more complex surgical manoeuvres. The major one is gaining time in the training on the living. These systems have been developed with the aim of autonomous training without systematic supervision by a teacher. But is an efficient teaching via virtual simulation possible without teacher or without expert? To answer such a question we have developed two virtual reality simulators aiming at providing an efficient education of operative minimally invasive procedures with a minimum mentoring by experts.

2. Material and methods

Our study has been done on the basis of two "patient-specific" simulators allowing to learn and train various procedures. The first one, HORUS©*IRCAD* [8-9], is a simulator allowing to virtually reproduce an ultrasonic image from a CT scan image or an MRI. It also allows to simulate the insertion of a needle inside a patient's body with force feedback in order to carry out two surgical manoeuvres: biopsy and thermal ablation (figure 1). In its educational version, the software proposes to do that kind of manoeuvre on a clinical base of five different patients suffering from liver tumours. When a student selects one of the cases, the surgical procedure he/she has to perform is described by the software. He/she then enters the simulation mode so as to control the US probe with one hand and the needle with the other, which will have to be inserted into the targeted tumour. The simulator offers a certain number of functionalities among which one of the most important ones is automatic evaluation. The system provides essential quantitative and qualitative information: the percentage of pathological tissue destructed in case of thermal ablation and the percentage of pathological tissue retrieved in case of biopsy. This information also indicates if the student went through tissues or not which did not have to be touched during the procedures as well as the position of the needle with respect to the target. It does however not give a mark. Being experimental, no rule of usage of the simulator is given. It can be used autonomously without any supervision by a teacher or in a supervised way. Both usages will be analysed in order to extract the advantages and drawbacks from each teaching mode, as well as basic rules of good practice.

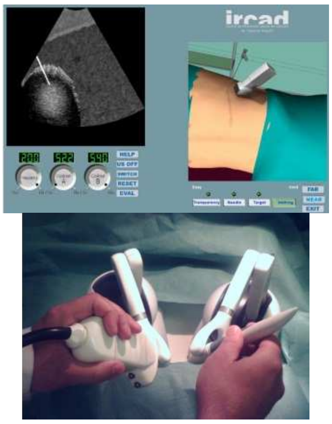

Fig. 1. Horus©ircad simulator allowing to simulate ultrasonographic imaging and needle insertion (left) with a force feedback device (right).

The second one, ULIS©*digital trainers* [9-10], is the first patient-specific laparoscopic surgery simulator using the new force feedback system developed by the Karl Storz company (figure 2). This system is composed of two to three entry ports with force feedback allowing for the insertion of real laparoscopic instruments that have been adapted for the system. Furthermore, the simulator includes a database of clinical cases that have been modelled in three dimensions from their CT images, and then textured photo-realistically for a rendering close to reality (Figure 2).

This simulator offers the opportunity of progressive training relying on six basic exercises to learn the basic rules of laparoscopic surgery. Users first have to learn camera manipulation alone. Then, they learn to manipulate two surgical tools. The following exercise consists in coordinating their movements between a camera on the one hand and a tool on the other hand. They learn then to coordinate their manoeuvres between two tools which have to interact simultaneously. The two last exercises are to learn how to aspirate blood coming from a haemorrhage and to coagulate points located inside the abdominal cavity, while controlling the tool with one hand and the camera with the other hand. Each exercise features a set of options, among which the inversion left hand – right hand (surgeons have to master their instruments with both hands) and the angulation of the field of view of the camera (30° cameras being more difficult to master).

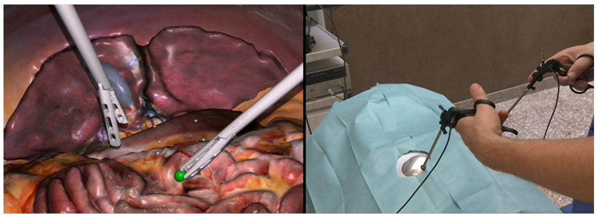

Fig. 2. Ulis©digital trainers simulator allowing to simulate laparoscopic surgery with a highly realistic rendering realized from patient-specific modelling.

The simulator features a student management mode in order to record all automatic evaluations provided by the simulator at the end of each exercise that has been done. Just like the HORUS simulator, this experimental simulator has no specific rule of usage. It can be used in an autonomous manner without supervision by a teacher or in a supervised manner. Both usages will be analysed.

In all cases, students were non-resident students in their fifth year of medical studies. The objectives of the training were:

- To Learn how to handle an ultrasound (US) probe, including mastering probe positioning, reading the associated image and spotting the visualized structures in space.
- To Learn the manoeuvres of needle insertion under ultrasonic control (for hepatic biopsy and liver tumour destruction through thermal ablation).
- To Learn basic manoeuvres in laparoscopic surgery including mastering the camera

positioning, mastering manoeuvre coordination between several instruments and mastering suction tools allowing for blood suction during haemorrhage and electrocoagulation tools used to burn tissues and coagulate blood with the electric arch of a specific tool.

The educative process was separated in three major stages: familiarization, training and evaluation. Thus the first stage of all our simulations was the familiarization that starts with a presentation phase of simulator functionalities and how it works. This presentation is done in the "demonstration" mode of the simulator, showing all the possible exercises but without recording the automatic evaluations provided at the end of each exercise. This initial companioning-type step is limited to 30 minutes, after which the teacher creates an account for the students so as to start their instruction.

At the end of the familiarization phase, students can then train on their own account in the training stage. As indicated, we have tested these simulators in an autonomous process and in a companioning mode in order to establish optimal rules of usage for simulators. This second stage was carried out with and without the supervision of the teacher. In case of no companionship, the teacher gave a "best way to use the simulator" document providing an educational pathway. The total length of this second stage was 20 hours for the HORUS simulator and between 10 and 30 hours for the ULIS simulator.

The last stage of evaluation consisted in checking on the simulator that a trained task has been acquired. This evaluation should ideally be done on an animal (real simulation), but because of economic and ethical reasons this was not possible. Of course the evaluation on HORUS and ULIS was different.

The HORUS evaluation stage has been set up to assess the efficiency of the simulator to learn ultrasonography and needle placement under US control. We opted for an "***external validation***" which consists in evaluating the learning of concepts of a domain on an operative mode that differs from the one used. Students are therefore facing situations during the evaluation on simulator that they did not encounter during the training phases. In our case, evaluation consists in performing ultrasonographic exploration of the abdominal cavity of a pregnant woman on a simulator, then in performing an amniocentesis[1] (Figure 3). Images as well as manoeuvres are comparable but still different. They nevertheless allow to efficiently control if students master the manipulation of a US probe, are able to locate anatomical structures on US images as well as if they can manipulate and coordinate their manoeuvres during needle positioning and insertion.

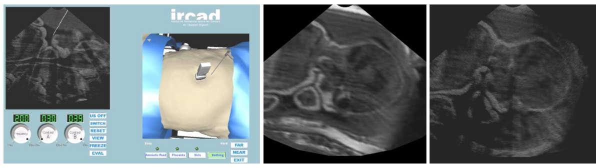

Fig. 3. Simulation of US-guided amniocentesis on a pregnant woman (left), MRI of the patient (centre) allowing to simulate a US image (right).

In a different way, the ULIS evaluation stage was an "***internal validation***", which consists in evaluating the learning of concepts of a domain in the same operative mode used during the training stage. We evaluated thus students on the same exercises as those that have been taught, favouring the two most complex exercises. After 10 hours, the chosen exercise will be carried out with a 0° camera. After 20 or 30 hours, the exercise was done with a 30° camera. In all cases, we choose the blood suction and the electrocoagulation of the haemorrhage exercises (figure 4). Indeed, these exercises have the advantage of requiring the simultaneous ability of controlling the camera, manipulating an instrument and coordinating camera/instrument. The teacher can then also choose to evaluate students on their weak points that have been revealed by the tracking of the automatic marking. The learning curve, which reproduces the marks saved at the end of each exercise, is indeed an efficient tool to spot the points students will have to work on.

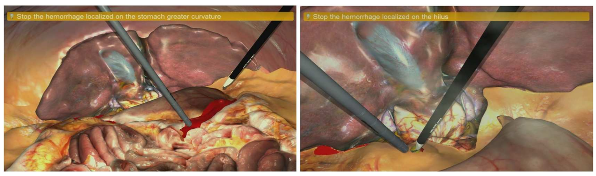

Fig. 4. Examples of the suction coagulation exercise of the ULIS simulator including haemorrhage, suction and electrocoagulation with smoke effect simulation.

3. Results

Whatever mode used, familiarization with the simulator requires an initial presentation step of functionalities and how HORUS works. That initial step, companioning type, remains limited to 30 minutes in the case of autonomous learning. It could be done by a technician who would merely present functionalities. However, in the case of HORUS, which does not feature an evaluation system for US probe manipulation, this would lead to an immediate problem: students would have neither recommendations nor understanding of the

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[1] Amniocentesis: using a needle to take amniotic fluid, which is in the "bag" around the fœtus protecting it.

guidance tool. We have noticed this quite rapidly during the first uses and it showed us a limit of the evaluation system of the HORUS simulator in the autonomous mode. This induces a first development rule of that kind of simulator:

Rule 1: autonomous learning on a simulator requires an automated evaluation of students by the simulator.

The use of the US probe not being evaluated by that simulator, the initial simulator familiarization through a companioning phase is hence mainly oriented towards the use of the US probe. During this phase, students can ask as many questions as they want to the teacher. This phase ends with an advice on how to use the simulator progressively, which represents an educational path. After the familiarization phase, we have tested an autonomous phase where students are free to use the simulator as they want. They have five clinical cases with greatly varying pathology localizations and also varying reading difficulties of the US image between patients. We noticed here that this free usage prejudices training. Indeed, most students do not follow the recommendations for use of the simulator provided by the teacher during the familiarization phase. Thus, the most standard use of the simulator in that mode complies with following pattern: selection of a patient and rapidly trying out the biopsy or thermal ablation manoeuvre. The prior exploration phase is then reduced to a minimum. After about five hours of simulation, students however realize that they are not able to carry out the manoeuvres. They then go back to the proposed educational path rather naturally. In the end, the freedom of manipulation logically entails losing time when learning on a simulator since its use is in this case not optimal, no educational path being provided. This evidence leads to a second rule of autonomous use of a simulator:

Rule 2: autonomy of use of a simulator has to be compatible with sticking to an educational path.

This rule is well known in the world of computer games and serious games, which propose increasing difficulties in the game, access to certain parts of the game being subject to the successful undertaking of previous “missions”.

Another important point regarding this autonomous training mode is the freedom of action of students, who can carry out the entire surgical procedure. In the HORUS simulator, the consequences of possible errors in the surgical procedure are not simulated but indicated at the end of the procedure. Students can thus virtually carry out serious mistakes that could lead to important postoperative consequences ranging from the necessity of a new surgical intervention to the patient’s death. Whatever error, it will only be indicated by textual information on the direct consequences of the procedure: patient hemorrhage, pierced healthy organs, etc. This freedom of action with consequences limited to merely written information induces quite some lack of concern from students towards the consequences of their errors. In the reality of training as it is currently taking place in clinical routine on real patients under the control of the teacher, students could never carry out such a manoeuvre, putting patients’ lives at risk. Students therefore rapidly make the difference between simulation, where they make sometimes dangerous manoeuvres, and reality, where they would be much more cautious and would evidently limit taking risks in terms of chosen approaches. It both has an advantage and a drawback. The advantage lies in the fact that students can learn from their errors and can try out complex manoeuvres they would otherwise not be able to test in reality. The drawback is the absence of mental immersion in the performed surgical procedure, leading to sometimes useless risks for patients. As we will see it later on, these benefits can be exploited favourably while limiting the drawbacks by adding a teacher behind students. This takes students back to the training mode they would have known with a real patient, what makes the virtual patient more real.

Another way to solve the mental immersion problem would consist in simulating the immediate negative consequences of an error, in particular by simulating continuous tension monitoring of the patient (including a sound signal leading to real stress in students when exceeding normal limits), an ECG[2] (noisy environment adding significant stress in case of heart failure) or hemorrhages (dropping blood pressure and bleeding). Adding a video showing a patient being taken to the surgical ER and undergoing surgery for the damaged organ could also make the system more complete and illustrate postoperative consequences of an error. In fact, all these systems would increase realism and student concern towards their errors, which are linked to their lack of perception of the consequences their virtual manoeuvres may have. From this, we deduce an additional rule close to the first rule but adding the concept of postoperative consequences of manoeuvres.

Rule 3: autonomy of use of a simulator requires automatic and immediate feedback on the efficiency of a manoeuvre and its consequences.

ULIS being developed after HORUS, it integrates the three defined rules, which means an automatic evaluation mode offering students fast and clear

[2] Electro-Cardiogram: system used to monitor a patient’s heart rate.

overview of their progress during the instruction. This "learning curve" is personalized and specifies a name, hence the necessity of creating an account. Furthermore, unlike HORUS, ULIS integrates an educative path developed as progressive exercises. Finally ULIS integrates direct feedback of error that could lead to the death of a patient. But we have pointed out that this virtual death raises other questions on potential dangers of a simulator on the psychological level varying from patient death becoming common place to possible trauma of students (though hardly probable). We therefore propose to clarify rule 3 by indicating the importance of the educational path:

Rule 4: in simulation, automatic and immediate feedback on manœuvre efficiency and its consequences has to be used according to the targeted educational objectives.

Finally, thanks to the evaluation stage, we notice the efficiency of each simulation to provide the awaited learning. On HORUS, we noticed that compared to the autonomous mode, training with companioning was clearly more efficient. Indeed, in the autonomous mode, we notice a significant variation between students in terms of efficiency of the needle insertion manoeuvre and the US probe manipulation during the exploration phase. On the opposite, in companioning mode, all students well master exploration under ultrasonography. Indeed, all related limits were overcome thanks to teacher intervention during simulation. Companioning was thus here an efficient solution to guarantee a good exploitation of the simulator. We could therefore notice that in companioning mode, HORUS is a particularly efficient tool for this teaching.

On ULIS, after the evaluation phase, we have noticed that 30 hours on the simulator seem to be sufficient to learn the taught basic manoeuvres, the best results being obtained by students who underwent three 10 hour cycles. These evaluations show however disparities. Some students for instance are rapidly able to master manipulation after 10 hours, while others have similar or weaker evaluations after 30 hours. This could mean that the simulator would allow to spot students with more difficulties in performing surgical manoeuvres and who therefore require more training time. It will be essential to check that hypothesis during the rest of the standard clinical training. The simulator is today too recent to guarantee this hypothesis

4. Discussion

Thanks to the last step of the process, the evaluation of students, we finally noticed that the HORUS simulator in companioning mode is a particularly efficient tool for the education of US exploration. However, compared to this exploration, needle insertion is not that well mastered by students, although it is way superior in autonomous mode. Though most students are able to carry out the requested manoeuvres virtually, some of them are unable to do them efficiently after 20 hours of simulation, 12 of which are specifically dedicated to that manoeuvre. This leads to three hypotheses: the first one is that HORUS does not allow to guarantee efficient gesture teaching.

The second one is that HORUS allows to learn needle insertion, but since this is a complex manoeuvre, not all students can learn how to do it in only 12 hours. The third one: HORUS not only allows to learn US-guided procedures, but also to select in 20 hours students who will be able to realize that manoeuvre with no danger for patients. It is obviously difficult to assess the truth of those hypotheses, the last possibility is however seducing and would match the current exploitation of flight simulators in selective mode. In order to check those hypotheses, more experiences in simulator use are required. Having an evaluation of simulator feedback in real hospital practice of students would further be greatly valuable, which is currently not the case. We do however think that the third hypothesis seems very likely and that the simulator in companioning mode probably allows for the extraction of sufficient information on learning and realisation aptitudes of a complex surgical manoeuvre, so as to be characteristic of the realisation ability. In the end, we can conclude that in companioning mode, a simulator can be used to evaluate learning abilities of a taught manoeuvre, method or reasoning.

During the exercises in the training stage of ULIS, we have also noticed that some students wished to be assisted or controlled by the teacher. In fact, the freedom of use entails the fear of not doing or learning manoeuvres properly. Although the software gives an automatic mark for each performed exercise, it cannot replace the reassuring presence of a teacher. Surgical training relying currently on companioning, this behaviour can seem natural, but it also points out one of the limits of automatic training. Furthermore, we have noticed that the initial use of the simulator systematically led to true enthusiasm in students whereas a prolonged 30 hour use was at times wearisome for some students. Repetitive and isolated learning of surgical manoeuvres can explain this. The risk of this lassitude is that manoeuvres may become commonplace, losing their realism, and students may lose their motivation for that kind of learning. In both cases, the intervention of a teacher during the training cycle can be a solution to both reassure students and keep up their initial motivation. We have noticed that this intervention can be reduced to the review of student evaluation and to the execution of a very limited number of exercises under teacher supervision. Thus, doing several 10 hour training cycles, including student evaluation at the end of each cycle, is a satisfactory solution to guarantee motivation and confidence. In the end, it is preferable to do three 10 hour cycles rather than a single 30 hour training ending with an evaluation.

Let's finally point out that we have used the simulator in two different environments: an IT room and one of IRCAD's training OR rooms. In the first case, students did not need to "dress up", i.e. wear the required compulsory OR outfit. In the second case, students not only had to dress up but were also confronted with a real surgical environment. We noticed in this second case a different approach to the simulator; manoeuvres never become commonplace and especially exercises become more realistic. Students were clearly more concentrated and trusted the simulator more, never comparing it to a game. However, we have to relativize these facts by the little number of students. A long term study will help checking this fact. This would mean that for learning even basic manoeuvres, real surgical conditions improve training.

5. Conclusion

We have seen the exploitation of two training simulators for interventional procedures in radiology and minimally invasive surgery. They allowed us to define 4 main simulator exploitation rules, in particular in autonomous mode. Our studies clearly show the feasibility of such training at the first training step.

Our work further highlighted an external consequence which was initially not expected. Indeed, surgical simulation provides a new vision of tomorrow's medicine. It improves student consideration of medical orientations which have difficulties in attracting the young generation, such as radiology or surgery. Attractiveness of new technologies and educational benefit of simulators give non-resident students the opportunity of carrying out manoeuvres which are usually forbidden thanks to virtual reality. This represents an attractive element for those difficult professions. Shall our hypotheses that we described in this chapter prove to be true, simulators could also allow to detect the skills and difficulties of each student earlier. This would ease recruitment and training of students according to criteria closer to professional abilities, essential point to guarantee tomorrow's medicine.

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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.

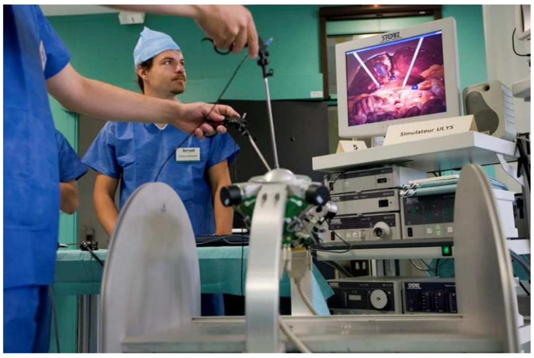


Figure 1: Hybrid simulator ULIS for surgeon training [11] combining virtual scenes inside a patient on the computer screen and real surgery tools with force feedback.

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).

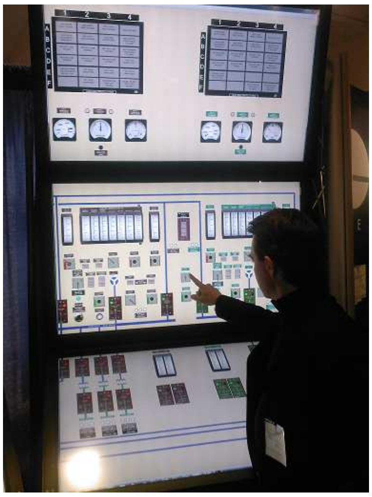


Figure 2: Hybrid simulator developed by GSE Systems for nuclear reactor control rooms: the three boards are scale 1 ontouch screens and all components are virtual.

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:

$$K_{sr} = HR_{mean} \,.\, HR_{max\ ampl}$$

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:

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

where $Y_i = y_i^* - 1$ and $\overline{Y}_i$: 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.

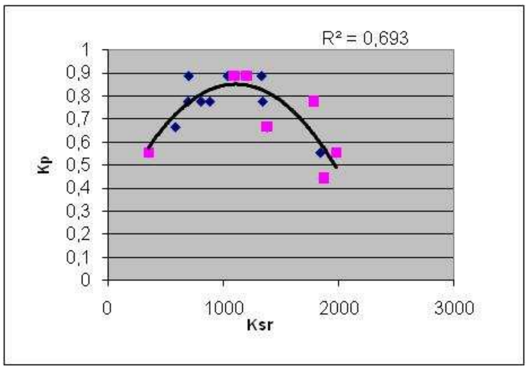


Figure 3 : performance coefficient K_p plotted vs reduced stress coefficient K_{sr} discriminates the No Stress Conditions (dark diamonds) and the Stress Conditions (clear scare) for the Stress-test' subjects.

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.

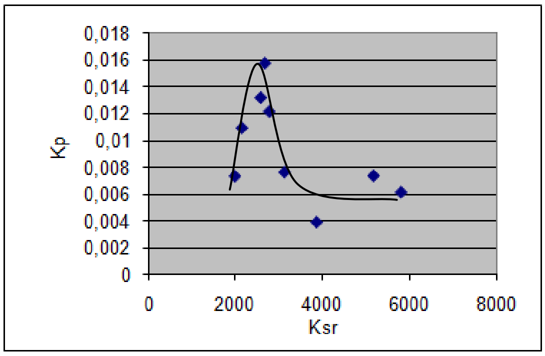


Figure 4: performance coefficient versus reduced stress coefficient for anesthetist residents not submitted to strong physical efforts.

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.

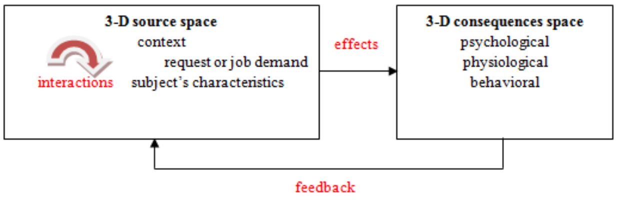


Figure 5: the two 3-D spaces model for short term occupational stress.

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.

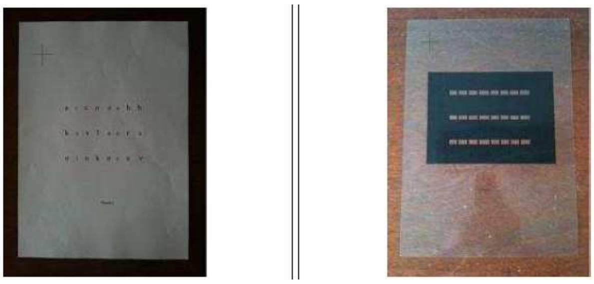
Further observations and discussions show that if the prescription book is used in its available version on a personal computer, the result is the same, but the main factor leading to this result is the complexity of the prescription book.

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).

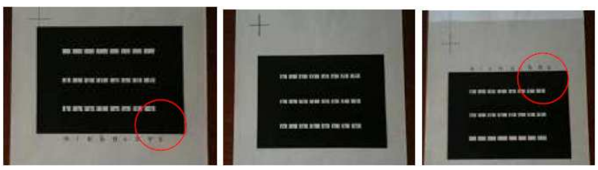


Figure 7a, b & c: Examples of shifting of the mask when using only the middle line.

- 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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Pilots needs and expectations: perspectives of simulation for training

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Abstract

The safety level achieved by civil aviation owes much to the use of full flight simulators. The use of these tools requires a disciplined organization, including a serious study of accident scenarios characteristics of operations. When these data are available, there are generally three forms of training, so called pedagogical classes, which can be adapted to the needs and expectations of the pilots.

1. Introduction

Civil aviation, with one accident in every 1.5 million flights is today inside time of justification of industrial cycle [1] following heroic time and time of hope.

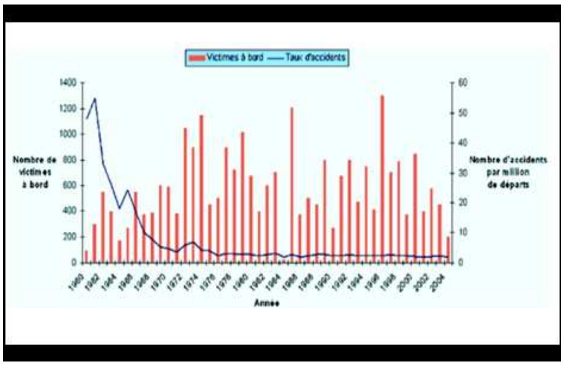

Figure 1: Accidents per million flights

But, as shown by the blue curve (Fig. 1) which accounts the number of accidents per million flights, we found that after a rapid progression between 1960 and 1980, the trend is now flattening, even if finer studies show that safety is still improving. Improvements are due to many factors but we must say that the simulation of flight at full scale contributed significantly to this positive evolution.

2. Use of full scale simulator

With these high-performance machines one is able to simulate hazardous flight conditions unsuitable in real flight training, such as smoke in the cockpit or severe turbulence. In terms of flight safety, to take full advantage of this type of simulation, you have to elaborate:

- a taxonomy of accidents (Fig. 2),
- a safety model (Fig. 3),
- a hazard cartography process (Fig. 4).

This approach allows the creation of scenarios well adapted for the type of killer [3].

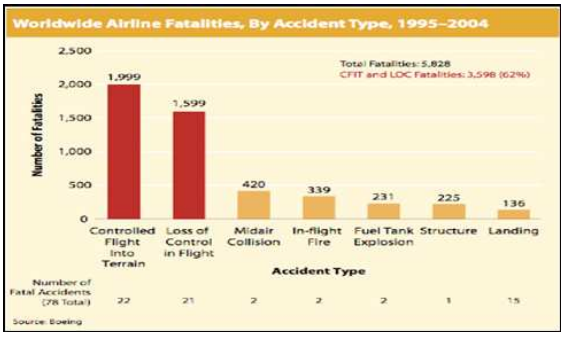

Figure 2: Accidents taxonomy

Figure 3: Safety model

The use of three pedagogical classes, that take into account the situation dynamic and the flight environment, is needed to effectively address both white sharks in civil aviation that are loss of control (LOC-I) in flight and controlled flight into terrain (CFIT).

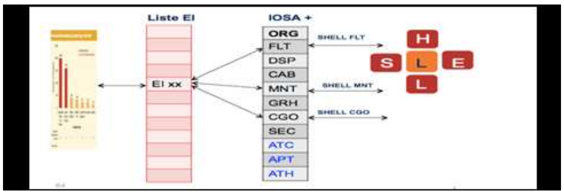

Figure 4: Hazard cartography

3. Applied Perspective

The analysis shows specifically that human factor was the primary cause of 80% of accidents. Even if the scenarios for third pedagogical class are mainly used for human factors training, and even if the debriefing by the instructor is efficient, the full flight simulation is not enough. On this point, serious games offer a range of solutions tailored to solve such a specific aspect of human factors, as decision making or situational awareness.

EHEST (European Helicopter Safety Team) shows the importance of accident rates in the first thousand hours of flight (Fig. 5) just after being qualified and within this range, the extraordinary contribution of the first hundred hours. A human factors expert will link this rate of accident to the corresponding three stages of expertise acquisition in the model of Anderson [2].

Therefore it is possible to build a serious game designed to emphasize the link between flight experience and safety. Then one will derive decision strategies tailored to the situations encountered.

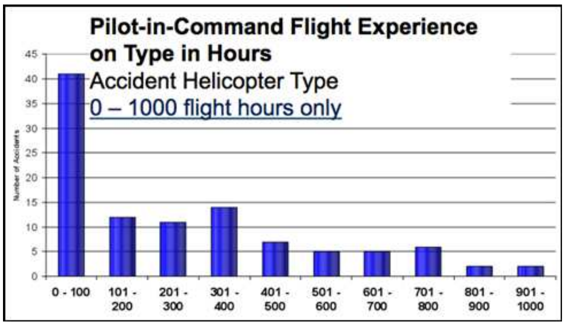

Figure 5: Helicopters' accidents

This process is not easy with a full scale simulation, and far more expensive.

In conclusion, we can see all the potential synergy in terms of safety, of a full flight simulation and serious games, these games that cultivate the human factor. We probably have a new source of safety improvement, and it is definitely cheaper. On our never ending quest for flight safety, multiplied by 30 during 30 years and by 100 during 50 years, let us play the game!

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Simulation or Serious Game?
The D.E.L.T.A. Model

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Abstract

This article's goal is to present a quite simple pedagogic model, both for learning purposes and to aid in the decision making process of professional projects. It will be useful mainly when, at the start of a new project, the conception team and decision makers will have to choose both tools and methods to better answer a particular set of requirements. Does the situation need to be addressed by teaching a series of technical tasks, tactics or strategies? Does the project aim for a large audience or a smaller group of specialists already possessing a set of professional know-how? Is it human factor or safety related? Does it aim at making people aware of a particularly overlooked problem? Is the project about evaluating capabilities, knowledge, what is the required level of realism in terms of situation, graphics or game mechanics?

All those questions and more will guide the conception team toward the creation of a simulation project, a serious game or a combination of both, a choice that will be more assured and easier as the major roles, stakes and limits of both models are clearly defined.

To tackle this task, five gradients can be defined, cursors to be adjusted to analyze the needs of the client and enable the team to identify quickly the correct answer regarding considerations of context, session rhythm and information dispatch to the learner. Also to consider are the cost and time of development, the technical aspects of game mechanics and the ability to evaluate the learners results based on the level of openness of the virtual world and the freedom of action.

1. Introduction

Simulations have proven their utmost usefulness by improving safety and procedures in the working environment by a tremendous factor. But it is now up to the serious games genre to set new grounds by improving on the user experience and providing him and the instructor a different set of tools and methods.

The DELTA model that I want to introduce to you is one that will allow you to better differentiate the two genres and clear your ideas about what serious games bring to the table, by removing the many confusions that often lead to approach serious games as a form of adversary for simulation, while it should be perceived as its more natural ally.

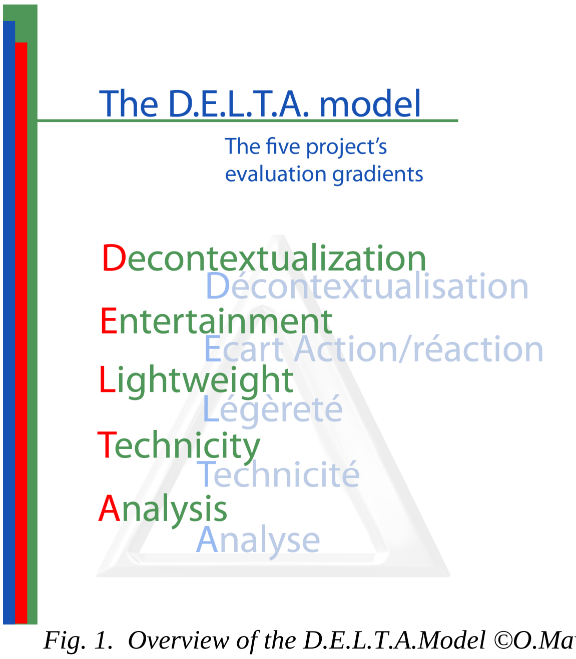

Fig. 1. Overview of the D.E.L.T.A.Model ©O.Mavré 2011.

2. The project evaluation gradients

The proposed model may be used both as a decision helping tool and an analysis method for already deployed projects. It is based on five key elements that represent the most noticeable trances observed in serious games as well as simulations projects. However, it is worth noticing that these observations shall not be taken as absolute rules. The term "gradient" was, indeed, chosen to represent the notion that all five notions are present, but in different format or proportions in both projects. Those observations shall yet be verified by putting in place some systems that will be presented at the end of this article.

We will begin by enumerating the five evaluation gradients, both from a serious game and simulation perspective, before illustrating the model's usage by analyzing a concrete project.

2.1 Decontextualization

The first gradient deals with issues of context and realism – or at least to produce realistic assets – both in terms of situations, graphics design and game mechanics. This principle answers a crucial limit of simulations which is that, although they are an essential tool to acquire a technical level in a pilot, technician or other activities, they almost exclusively depend on the ability of the instructor in terms of understanding the internal reasoning of a learner, to decipher its psyche. A difficult task that spans over a lengthy period of time, from the hours-long simulation sessions, to the debriefing meetings.

But assigning the part of a doctor to a doctor within a simulation creates, by definition, a cognitive bias, because of the natural learner's ability to build fences inside his known environment, defenses that will more or less consciously generate answers to the simulation that will not truly match his psyche but what he seems is expected of him, either but his instructor or but the simulation itself. Therefore, he will probably try to provide answers that are "by-the-book" more than what he feels is correct or that matches what he will truly do when confronted to a real life situation.

Serious games offer a simple mechanism to address this issue: it is called decontextualization.

This concept is all about putting the learner inside a context in which his professional reflexes will be neutralized, allowing to reach for a deeper level of the brain mechanism of an individual. This context change answers to different objectives: It allows, for example, to bring into light the cognitive biases of a group who routinely works together, and therefore, is working on an implicit context base to exchange information. The obtained result actually resembles the experience of adding a new member to a team that's already seasoned, showing the lack of precision in the communications that are balanced by the habit of working with each over.

Furthermore, this tool prevents another classical problem of simulations which is that learners usually "look for the problem" simply because they are in a simulation and, knowing the context in which they are, they think they can outsmart the system by figuring out the failure before it accures.

This need to get the learner out of his preconceived environment is also due to the fact that most accidents seem to come from, not one single cause, but an accumulation of small errors, deficiencies that put the operators out of their usual environment, the situations they prepared for in simulations.

It is also worth noticing that this mechanism justifies and gets rid of the complexes that come from using serious gaming (the process of utilizing a pre-existing commercial game for serious games purposes, used as such or with added adjustments in terms of graphics or scenarios) even if they do not match the learners trades, to test their specific behaviors and retrieve data not biased by their reflexes like their cognitive skills to work in groups or their reaction to unforeseen events. Finally, we can note that the mechanics of decontextualization are used in some serious games, in order to convey the same problem from different points of view, as in the case of the game "PeaceMaker". (1) or the series "Global Conflicts (3).

2.2 Entertainment

The gradient of delayed action and reaction generally describes the pace of the interactive session, according to two main parameters:

- The first data to be observed is the rate of feedback from the simulation - or instructor – given to the learners. A serious game project, using the mechanics and addictive systems of classic video games products, will aim at a real-time feedback - see the example of the game "Renaud Academy" studied at the end of Article (2) - this mechanism of immediate gratification is the basis for entertainment by which the player will feel committed to keep the experience going and improve his results. The gratification of all the player's actions, positive or negative, will be displayed by a simple reaction of the interface, a sound, a score, access to additional content (image, video, extra level, etc ...). The simulator's strategy, in contrast, will be, in most cases, not to provide clear and live feedbacks to the learner's actions. There are several reasons for this behavior: first, to show students the consequences of their mistakes, allowing them to make the necessary corrections themselves, or because the feedback will be made only during the debriefing phase after the session. In the case of a simulation, this return of information will also depend much more on the expertise of the instructor than on the automated tools that are put in place inside a serious game, as we will show when studying the analysis gradient.

- The issue of the pace of the game / simulation can also be expressed by the management of playing time. It will, almost exclusively, happen in real-time when talking about a simulation, the instructor only exceptionally freezing the session to raise awareness of a problem to the learner. This time management will also provide a mechanism for creating "slow beat motion" that will be an integrated part of the experience of the simulation.

2.3 Lightweight

The lightweight - or heaviness – gradient, in terms of development and deployment of the project will actually be a result, at least in part, of other choices made, as much as the budget constraints and mode of distribution of the project.

Because of its material aspect - especially in the case of a full scale simulator - and its realistic technical constraints, the simulations are generally more expensive and time consuming to develop the serious games, but beyond these obvious facts, one can observe several unique features: thanks to their ability to deploy on light equipment (PC internet, smartphones and tablets) serious games could find, with varying degrees of success for now, new business models such as the distribution fee online, sponsorship, ad insertion, or even the distribution of actual physical content in stores. This choice is reinforced by the playfulness of the product and its technicity that is adaptable to a wide audience. Conversely, the frequency of use and general life cycle of the product seems superior in the case of a simulation, because of the "replay value" element - the ability to replay while keeping an interest to the game - due to more freedom of action and strategic choices, and the general duration of a session which multiplies the elements of choice.

For the user this time, we note that the full scale simulators generate very strong logistical constraints: They can often be booked twenty-four hours a day, with long sessions of over an hour, which generates a schedule reservation that can hardly meet the needs, making learning fragmented.

Instead, a serious game session can be done in ten minutes, allowing the learner to repeat the experience in less time on hardware affordable PC-style view of smartphone and other IPad, which facilitates access to more users, and its perception as an object of fun. The learner can even consider doing this work, which he sees as entertainment, at home or between two tasks during his work, which will allow him more freedom, will create a more effective learning by repeating curve and above all, this will allow him to question the game, to test the limit cases more easily than before an instructor. This kind of tool will thus disinhibit the learner and probably get different results and different data than the ones obtained from a simulator.

It allows to play down the failure that can be a real drag on a simulator and makes it easier to deal with critical cases (death of a patient, serious incident of a device, etc ...) as well as ward off reactions clearance that are attacks against the realism of the simulator.

2.4 Technicity

This gradient measures the technical preconditions in order to perform the simulation. A simulator will require most of the time a trade expertise and a knowledge base of the simulated domain. Conversely, a serious game looks for the widest possible audience. The gameplay and game mechanics will not have the depth, realism and sharpness of a simulation - which is anyway not its part - but will aim to transcribe the cognitive load associated with a task or series of tasks, adapting it to simplified controls, in order, not to convey a purely technical expertise, but to enable learners to quickly grasp complex situations, to raise awareness of other issues related to an activity, but that are not treated or treated in a partial way in simulations (issues related to human factor problems incidental to a technical task, moral issues like in the game "global Conflicts: Palestine" (3)) or to allow a more general audience to understand a field in which they know nothing about (students in their first year of studies, supervisory staff, a member of a multidisciplinary group with significant needs for cooperative learning and therefore understanding of various issues, etc ...) .

2.5 Analysis

We can establish a final gradient of project qualification by taking into account some parameters like the openness of the virtual world, the freedom of action given to the learners and their corollary, which are the means for evaluating the session:

- A simulation will provide in most cases a mathematical model or at least an algorithm describing a sequence of events based on assumptions or pre-developed scenarios of actual incidents reproduced with a maximum commitment to realism. The goal is to leave the learner free to act, to experiment with tactics, as far as possible, his strategic choices. In return, the performance evaluation of learners depends, to a large extent, solely on the knowledge of the instructor. Mechanisms for automatic validation, even partial, are often very difficult to implement and are quite often targets of criticism from the learners.

- Conversely, a serious game will take place in a much more closed environment, in which the freedom of action and choice will be smaller, but will offer, thanks to the introduction of stricter rules, a more precise set of tools for evaluating the performance and enabling a more efficient automation.

The desire to open, to leave a wide range of learners action, whether or not to implement an evaluation system based primarily on instructors, will give a strong indicator of the way the project aims at.

3. Application

Applying the Delta model to actual cases of serious games projects or simulations allows us to understand the linkages and complementarities between the two models. Consider the most striking case: Renaud Academy. This product was developed to train some fifteen thousand sellers of the company to sales interview situation, in place of e-learning program developed at great expense and had shown its limits (70% of learners leaving the training).

The game is interesting to study because it is based on highly contextualized situations, which would bring him closer to a simulation, but by offering a system of instant return of information and based on instant gratification (scores, standings, unlocking further missions, etc ...). Moreover, even if the gameplay reproduces realistic actions, it provides game actions whose technical level is accessible to all (quizzes, phase in which the player intervenes only to identify errors made by another seller whose actions are controlled by the system, etc ...). It is deployed on light medias and the results analysis is automated through simple actions dialogues nested types. He returns therefore, ultimately, to the category of serious games, but by taking specific elements from simulations.

4. Discussion and Conclusion

4.1 Discussion

Beyond a simple analysis tool of what already exists and an aid to establish a working production sheet, our model could be utilized to bring into light the drawbacks of existing projects regarding their initial objectives and determine the ways to fix them, by observing analog projects in the opposite field, simulations or serious games.

The establishment of rigorous protocols aiming at putting both types of projects to the test and evaluate their complementarity seems like the next logical step to the work presented in this article. Such effort should present us with new leads, by taking into account, for example, the concrete results observed in both fields of study, from the original designers standpoint as well as from the indications given by the use of the model.

4.2 Conclusion

The final goal of this model is to allow for a more accurate awareness by the key players in both fields, knowing that a comprehensive answer to the complex issues regarding human and organizational factors will certainly demand for projects combining both approaches, on filling the gaps of the other. These projects should be designed like those from the ground up.

This different view will also require a lengthy period of rigorous explaining and teaching of the complex issues and method used. This is particularly true for serious games professionals, who suffer greatly from the “entertainment” label linked to their product from the perspective of the decision makers. This article aims in this very direction.

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Training Incident Management Teams to the Unexpected:

The benefits of simulation platforms and serious games

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

Abstract

Training Incident Management Teams to manage unexpected situations is crucial to enhance firefighters' safety, their performance as well as public confidence. In France, the Civil Protection community has been using simulation platforms to train Incident Management Teams (IMTs) to fire events for over 10 years. The use of simulation platforms offers a number of advantages, by creating distributed cognition situations and truly unpredictable scenarios. They significantly contribute to improve *training IMTs to the unexpected*, *testing* new configurations, and *comparing* organizing modes. This article aims at sharing Bouches du Rhône Fire Department (SDIS13)'s experience in doing so, and at presenting the results of several research projects involving the use of simulation settings.

Introduction

When firefighters arrive on scene, they often have to deal with ill defined situations in which urgent action is required to save lives and properties. Training individual firefighters and teams to manage high tempo and ambiguous situations is therefore crucial to their own safety and performance [1]. Fire departments use a number a techniques to train their members, ranging from full scale exercises to table top exercises. In France, the Civil Protection community has been using simulation platforms to train Incident Management Teams (IMTs) to fire events for over 10 years. This article aims at sharing Bouches du Rhône Fire Department (SDIS13)'s experience in doing so, and at presenting the results of several research projects involving the use of simulation settings. The benefits are threefold: simulation platforms are found especially relevant for *training IMTs to the unexpected* (1), *testing* new configurations (2), and *comparing* organizing modes (3).

1. Training to the unexpected

SDIS13 simulation platform provides a virtual reality based environment in which firefighters have their own avatar, can walk, drive or fly and are able to take actions with direct consequences on the situation. The figure 1 below displays a general view of such a platform. We wish to highlight the two following key features.

DISTRIBUTED COGNITION

Trainees hold various functions, each with different locations (booths) on the platform: division supervisors, branch directors, air resources pilots, Incident Command Post staff … As a result, each trainee has access to and perceives only a piece of reality, a situation described a distributed cognition, mirroring more accurately a fundamental property of real life situations. This makes it possible for trainers to observe finely and to debrief collective sensemaking processes that construct and maintain situational awareness. Sensemaking processes all especially important in crisis situation. Crises can ultimately be defined as the collapse of meaning, a situation in which the world stops behaving according to expectations. Sensemaking is what is left for firefighters to build a more predictable and stable world in which collective action becomes useful and effective again [2].

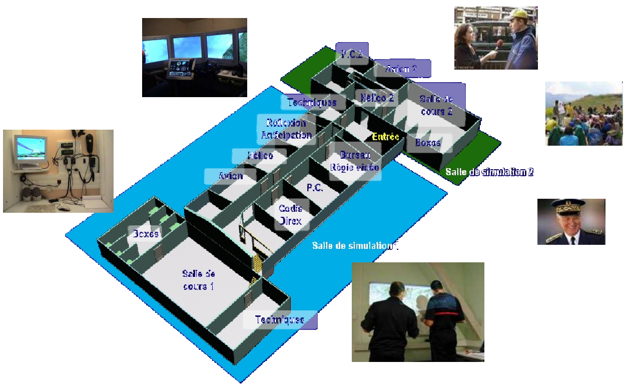

Fig. 1. A firefighting simulation platform

THE 3D ENVIRONMENT REACTS TO TRAINEES' ACTION

For instance, when pilots drop retardant or division supervisors start a backfire, cut lines or spray waters, their actions have direct consequences on the fire behavior and spread, as generated by the simulator physics model.

The first advantage is the objectification of the team's performance. With identical initial conditions, it becomes easier to compare outcomes, measured by the number of hectares and structures burnt. But the main benefit comes from the development of systemic phenomena.

Indeed, it is now well known by researchers that organizational success or failure is an emerging organizational property. For instance, organizational accidents often happen because small errors recombine in unexpected ways, potentially triggering catastrophic outcomes [3]. In simulation platforms, trainees' variations in performance and the reactions of the simulator interact to create **truly** unexpected scenarios. This is noteworthy because "classic" scripted scenarios do not take into account the interdependences between all situational variables. Moreover, they are designed *by firefighters for firefighters*. The point is that all situations that will be imagined will remain bounded by conceivable common expectations. Thus, we found that creating the conditions for the unexpected to happen in a dynamically interdependent simulation setting is much more effective than trying to *design "unexpected"* scenarios, a phrase that sounds like an oxymoron.

2. Testing: the case of aerial surveillance

NEW TEHNOLOGIES, « OLD » ORGANIZATIONS

Wildland aerial firefighting has seen a number of recent innovations, especially in the field of air intelligence capacities. Examples are satellites, Unmanned Aerial Systems, remote sensing technologies (e.g. electro-optical cameras), etc. Several benefits are expected from these systems, including real time information acquisition, fire detection, perimeter mapping, fire behavior assessment. The new quality information will feed new intelligence and decision support systems in order to reduce both risk and cost, by diminishing firefighter's exposure and flight time in smoke and low visibility situations.

Within a *systemic* view of organizations, the environment is in dynamic interaction with four subsystems: objectives, technologies, organizational culture, and structure. As a result, if technologies change, so should structure. Objectives and organizational culture are assumed to be more stable.

Many pieces of evidence show that firefighting organizations are just starting to figure out how to integrate these technologies. The US wildland fire community has raised this problem in its 2009 Quadrennial Fire Review: "Fire suppression in the next decade will begin a transformation process driven by technology, requirements for greater mobility and agility, and suppression strategies that will demand new levels of flexibility and precision" [4]. But the potential for problems is still present, because objectives will remain the same, thinking is just starting to adapt the systems' structures and organizational culture is slow to change. In France, SDIS13 has just engaged optimization studies that we report here below.

IMPLEMENTING REMOTE SENSING TECHNOLOGIES IN SOUTHERN FRANCE

SDIS13 mobilizes a Cessna equipped with spherical electro-optical cameras, flying during high risk periods. See figure 2 below. Video streams are sent to the Incident command post (ICP) and dispatch center.

Fig. 2. Cessna equipped with spherical electro-optical cameras

If nothing changes in structures, there are four types of risks. The **upward risk** comes from the fact that real time and rich information is delivered to high hierarchical levels that could be tempted by micro-management. The **downward risk** is due to the fact that real time and rich information is delivered to low hierarchical levels, possibly leading to unwanted local initiatives. The **outsiders' risk** comes from the awareness that videos could be communicated to other Emergency Services, Media, public, or legal inquiries. Finally, the **organizational risk** would realize if the cognitive load is increased by the video device. This risk is exposed by Simon in the following terms: "an information processing sub-system will reduce the net demand on the rest of the organization's attention only if it absorbs more information previously received by others than it produces" [5].

To sum up, the promises of new technologies of reducing risk and cost are not "naturally given". Organizations are made up of interacting sub-systems: objectives, structures, culture and technologies. Updating technologies triggers non trivial adaptations in structures and organizational culture.

MOVING TOWARDS SOLUTIONS

Simulation platforms enable to test different configurations, how they perform in similar operational conditions and to observe closely changes in sensemaking and decision making processes. The actual organizational behavior (vs theoretical behavior) becomes also more salient. But even more importantly, *learning by trial and errors becomes possible.* Errors significantly enhance the optimization of organizational processes, for real operations or operators' training. This project is currently under progress at SDIS13, but its preliminary findings can be reported.

First, the arrival point of the video stream in the Incident Command Post (ICP) was initially placed in the anticipation section. It proved to be sub-optimal because the operation section of the ICP was continuously going back and forth to the anticipation to monitor the fire perimeter moves. As a result, the anticipation section became a situation room reducing its planning capacity.

Second, the plane is currently staffed by a pilot and an operator who focuses on points of interests, zooms in and out, according to orders given by the ICP or the Operation Center. It was found relevant to staff the plane with an additional single resource, an experienced firefighter that could take initiatives, as to where the video should be directed to, and that could engage in discussions with ground personnel on fire behavior activity and tactics to be engaged.

These changes will be implemented for the next fire season. As a result, tests performed on simulation platforms allow operational organizations to gain time on their learning curves.

3. Comparing: The France-USA project

BACKGROUND

Vulnerability to wildland fires increases with the conjunction of three heavy trends: climate change, expansion of the wildland-urban interface and fuel growth. This situation makes large wildland fires more frequent, complex and dangerous, as recent fire history around the Mediterranean coast and the western US proved to be the case (see figure 3 for the US). The US Forest Service even coined new terms to describe these greater, larger fires, and longer fire seasons occurring irregularly within and across regions: mega fires, asymmetric fires, national significance fires…

Cross-comparison between two countries, two histories, two "worlds", becomes all the more interesting than we can reasonably predict when firefighters from both nations have come up with different responses and solutions to the same challenges, setting the stage for fruitful cross-pollination.

THE FRANCE-USA PROJECT

The project started as an exploration of innovations in wildland fire management methods, with a special focus on organizational dynamics during the suppression phase in wildland-urban interface fires. The comparison involved two territories: Southern France and the Western US.

In France, the project participants include: University of Aix-Marseille (CERGAM), France's Civil Protection Training School (ECASC), Bouches-du-Rhône Fire Department (SDIS 13).

In the US, the project participants include: University of California Berkeley (CCRM), National Advanced Fire & Resource Institute (NAFRI), National Wildland Fire Lessons Learned Center (LLC), US Forest Service - Fire and Aviation Management (FAM).

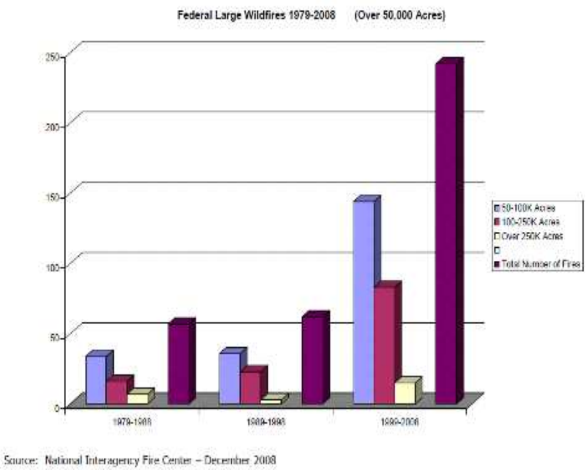

Fig. 3. US fires over 50,000 acres since 1979

THE COMPARISON PROCESS

The comparison process involved the cross-observations by French and US firefighters of fire operations, crew level and incident management team trainings, and full scale exercises in both countries. Archival data were also examined, and joint simulation exercises were carried out on France's civil protection Virtual Reality-based (VR) training platform. The project was designed and conducted by a team of researchers from Aix-Marseille University and UC Berkeley.

We focus here below the joint simulation exercises. The comparative features between fire suppression methods are always difficult to agree upon because they are seen as highly contingent on local or national contexts. As a result, people feel as if they are comparing apples to oranges. To overcome this traditional problem, joint simulation exercises were especially designed for the comparison. They involved the Atlanta-based National Incident Management Organization team and the most experienced French incident management team from SDIS13 (one of the southern France's leading fire departments in wildland firefighting). Both teams were put separately in the exact same operational conditions and performed one after the other on three different scenarios. The experiments were conducted on France's Civil Protection virtual reality based training platform. A specific website was dedicated to the simulation exercises: ccrm.berkeley.edu/hro-fires, providing further details on the experiments. The exercises were broadcast live online and now can be downloaded for interested researchers. They were observed by French nation experts in wildland firefighting. IMTS debriefed their own exercises, observed the other IMT's performance and conducted crossed debriefings. The data collected (over 200 hours videotaped) was coded by researchers.

Debriefing of the NIMO team's exercise

Mike Dueitt (US Forest Service) playing a branch director during the exercise

Col. Luc Jorda (yellow vest) discusses tactics with his command and general staff

French pilots "flying" a CL 415 over the Devil's Hole fire

Fig. 4. US-FR simulation exercises

LESSONS LEARNED

A number of lessons were learned from this comparison, which we present here below and word under the form of recommendations.

Common directions for French and US IMTs

Improving the quality of sensemaking by making collective moments more mindful and effective.

Sensemaking relies on the quality of interactions among firefighters and particularity in the incident command post or during morning briefings, strategy meetings, planning meetings... Heedful interrelating can be achieved by enforcing norms that encourage people to speak up when things don't make sense, to value respectful interactions based on integrity, honesty and trust, to avoid "can do" attitudes and reward active listening versus advocating.

Improving training tools to better handle complexity.

Today's trainings emphasize the application of standardized processes, and assess individual reactions to scripted inputs. Although absolutely necessary as a first learning stage, they could be complemented by new types of training that integrate incident's complexity to build and train resilience capability. The simulation platform such as the one used by SDIS13 provides a way, although not the only one, to progress to integrate complexity and resilience. Including bio-feedbacks (such as "activation" levels, measuring indirectly stress) can also help by teaching individual and groups to regulate their emotion more effectively. Filming trainees and debriefing by showing the tapes seems to be more effective than oral presentation urging people to be aware of their biases.

Working closer with communities

In the WUI, the adaptation of communities to fire prone environments is largely dependent on social dynamics before, during and after fire events. Understanding better through research efforts and lessons learned from notable fires is certainly a first step. In addition to existing community dialog, awareness programs, legal obligations (construction norms, clearing around homes …), and common trainings could also build up communities and firefighters resilience. It is even possible to develop a virtual reality platform (such as the one used by SDIS13) that recreates WUI fire situations and to jointly train emergency responders and residents through real-time interaction, in their own community/surroundings. In engaging in community-wide training exercises, residents and emergency responders will experientially learn how to react in fire situations and identify corrective measures to reduce their collective vulnerabilities to wildland fires. For instance, the differential impact of varying vegetation clearings will be experienced by homeowners.

Benefiting from the US experience in France

The ability to rapidly put out nascent fires requires different qualities than to manage a large scale incident. During initial attacks in France, the organization is strongly centralized around the incident commander who holds the big picture and sets a tactic based on decisive actions with heavy duty resources. As the incident gets more complex, the organization should decentralize to better adapt to the reality of divisions and to initiate opportunistic actions with lighter resources, which impact on the incident will make possible decisive actions later on. France can prepare for complex and long duration operations by:

- Decentralizing its organization, within the control of processes adapted for large incidents such as the US Incident Command System framework.
- Diversifying the tactics used. French firefighters fight fires from the road/special track systems generally, with prepositioned permanent dip tanks and water reservoirs for engines to fill their tanks. They do not have hand crews or equipment that constructs fire lines. France's fuels, geography and population density make indirect attack more difficult to implement. However, this was recognized a source of improvement.

SDIS13 has already engaged in both directions with the support of the US Forest Service.

Benefiting from the French experience in the US

The following items concerns fire suppression in the wildland-urban interface only.

Earlier detection of nascent fires

Some of the following actions implemented in Southern France could be of interest: automated fire detection cameras covering high risk areas, air surveillance planes equipped with HD gyro-stabilized color/infrared cameras, a dense manned lookout network, community staffed ground patrols, ground sensors.

Shorter response time

Not only are significant ground resources prepositioned evenly over high risk areas during maximum burn periods, but air tankers flying patrol fully loaded with retardant are constantly in the air with a response area of approximately 10 minutes. As a result, once a nascent fire is detected, several retardant loads are dropped within 10mn. Moreover, a dense track system (for fire trucks only) has been developed for years to ease the access of incoming resources. Finally, a proactive dispatch, staffed with professional firefighters receives the detection warning and starts suppression operations by sending massive air and ground resources to the fire location, takes the first steps (e.g. giving dropping authorizations to air tankers)... before the first IC is on scene. Functions (command, operations, planning, and logistics) are then progressively transferred from dispatch to the incident management team.

Organizational dynamics at early stages

Within the first hour, a command and general staff of 9 officers are fully operational in the command post. The command post has two parts: the "noise" room and the "silence" room. The noise room is dedicated to operations with the situation officer, operations officer, logistics officer, media officer and the operator in contact with the CODIS. The silence room is staffed by two officers, the anticipation chief and the logistics chief, who analyze possible developments and propose strategies and subsequent actions to the IC. A dedicated officer in direct contact with the IC coordinates the command post. The main point is that a command and general staff is rapidly operational, and in general is oversized given the fire complexity, but this anticipation is precisely what avoids catastrophic developments.

A number of projects are being considered or currently conducted to pursue the partnership between France and the US, some of them through the simulation platform: *developing the use of the Incident Command System (ICS), training IMTs to joint operations, and collaborations on innovative technology projects.*

Conclusion

Training IMTs to manage unexpected situations is crucial to enhance their performance as well as public confidence. The use of simulation platforms offers a number of advantages, by creating distributed cognition situations and truly unpredictable scenarios. We have described how they contribute to improve *training*, *testing* and *comparing* processes.

However, recreating the systemic properties of real life organizational dynamics brings about its own limitations. Trainers have a harder time grasping the complexity of continuous interactions and cannot rigorously assess teams' ability to detect weak signals early and to contain errors.

One of the interesting findings of our research project is the development of coupling measures that quantify the nature of interactions going on within the team [6]. This measure is based on identifying "who talks to whom and how long" and can be easily automated during trainings or even real operations. It is especially useful because it captures systemic phenomenon by analyzing interaction network properties, such as density, centrality, structural holes...

It also quantifies how much thinking/sensemaking is going on and where this is located in the organization. For instance, a team about to make an important strategic decision should make sure that it is functioning in a loosely coupled mode. Conversely, once an opportunity has been detected and the team is engaging the fire, then the whole organization should move towards a more tightly coupled mode. Tests have been performed during the FR-US exercises and have proved promising.

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Serious Game & Simulation
Immersion in Virtual Reality tools to change people's behavior facing the risks

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Abstract

Taking into account the risks, the aspects related to human and organizational factors are essential. Decision-making, collaboration, risk of error are all elements on which each manager must focus its attention. We are here concerned by critical and sensitive points of everyone's managerial behavior. The objective is threefold: assess interest and opportunities offered by virtual reality behavioral learning tools, measure the need or not to change participants in their usual work universe (by focusing our attention on the activity), determine the opportunities offered by virtual reality platforms.

The evaluation of these goals and the conclusions we can draw will be asked later.

1. Introduction

Whether through human factors studies or through works bearing on the decision (decision making and meaning making), the preparation of frameworks to decision-making in emergency situations is complex. We have written previous articles [1, 2] on the decision facing emergency and complexity in which we suggest axes of progress for executives, managers and charter engineers.

The main difficulty lies in the need to confront the learner to the action (I know from what I realize, including my errors) without however weakening (failure introduces a bias for the future).

We thus seek to put learners in situation and encourage them to develop decisions (individually or collectively) in a stressful time interval. The risk of perceptual and cognitive bias is ubiquitous [2, 3] in the decision-making scheme they implement. 3D and immersive virtual reality tools appear to be of the most suitable to produce credible situations affecting the behavior or reflex acts. We thus seek to test two factors: the effectiveness of these tools to produce educational exploitable situations, and the interest of a decontextualization of situation development for a non-drama concerning choice and errors.

2. Equipment and methods

We have retained an experimental methodology for support or reverse our assumptions. We are building an inter-enterprise educational action with actors from various backgrounds. This action includes the decision in an emergency situation.

In this framework, we build a pedagogical program and we rely on various tools of virtual reality. Participants expressed their reaction after each use of tools in two ways: by completing a questionnaire we have developed and by responding to a video-recorded interview.

We use four simulation tools in one day. First, it is a public game, on a classic game console. The collaborative aspect is put forward. The interaction generates via a joystick on a television screen. Secondly, we use a serious game which requires a four people network. The third tool is a software used for the training of emergency workers. It is immersive, and thus it allows through an avatar to get involved in the created event. Finally, we use an immersive platform of Virtual reality: the participants must perform actions in a virtual world, each corresponding to a decision. Biases are also introduced in the scenario (figure 1).

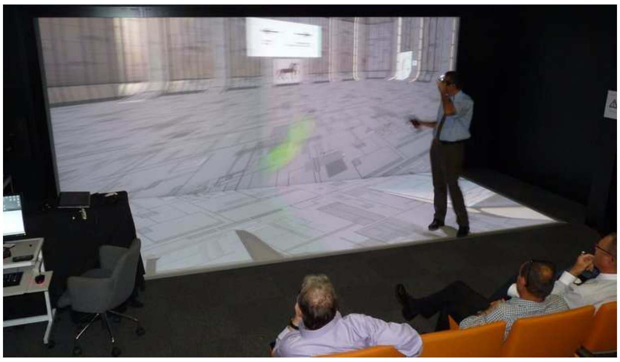

Figure 1: immersive platform of Virtual reality.

3. Results

Among the three tools, two are of real interest. Divert the Wii game is useless: instructions and constraints are not enough discriminating for use in teaching, while simulations and 3D virtual reality platform increase individual and collective skills in a meaningful way.

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