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A Method to Design a Multi-Player Educational Scenario to Make Interdisciplinary Teams Experiment Risk Management Situation in a Digital Collaborative Learning Game: A Case of Study in Healthcare

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Abstract—In recent years, there has been an increasing interest for collaborative training in risk management. One of the critical point is to create educational and entirely controlled training environments that support industrial companies (in transportation industries, healthcare, nuclear…) or hospitals to train (future or not) professionals. The aim is to improve their teamwork performance making them understand the importance applying or adjusting safety recommendations. In this article, we present a method to design multi-player educational scenario for risk management in a socio-technical and dynamic context. The socio-technical situations focused in this article involve non-technical skills such as teamwork, communication, leadership, decision-making and situation awareness. The method presented here has been used to design as well regular situations as well as critical situations in which deficiencies already exist or mistakes can be freely made and fixed by the team in a controlled digital environment.

Keywords—collaborative virtual environment, serious game, risk management, communication, healthcare training, simulation

1 Introduction

In recent years, there has been an increasing interest for team training in risk management especially in case of socio-technical and dynamic systems.

Many reports [1], [2] point the importance to design educational environment and educational programs to reproduce with high fidelity the professional environment and train staff on risk management. Experts stress that training future professionals and professionals on real-life based events should be a good way to increase their performance if they encounter the same kind of situation. Involving the teams to investigate inter-professional collaboration in a virtual environment should enable them to experiment risky conditions, to identify errors, adapt their behavior, make suitable decision and then evaluate miscellaneous causes of near-miss.

On one hand, the investigations against the most tragic accidents lead most of the time politicians and managers to establish new rules, policies or recommendations to prevent new similar accidents. On the other hand, some professionals often interpret new rules and procedures as a stronger control of their activities.

Others consider the rules, policies or recommendations as a problem due to the stacking of rules and/or the rules themselves. In addition, human factors such as communication, teamwork\dots represent a recurrent root-cause of accidents.

One of the critical components of a comprehensive strategy to improve the safety in transport industry, as well as in healthcare is to create educational and training environments that support providers to train teams to improve their performance making them understand the importance applying or adjusting safety recommendations.

Several markets have already been addressed to train on emergency situations such as medical emergency[3], military intervention[4], bio-terrorism preparedness, nuclear emergency[5], chemical industrial risk[6]…

However, these works fails to consider the human factors such as communication which is listed among the main root causes of accidents.

They mainly focus on scheduling or technical skills and their approaches are centered on the individual aspects of risk management.

2 Purpose and goal

To teach and monitor non-technical skills such as teamwork, communication, leadership, decision-making and situation awareness, a digital collaborative environment has been designed to represent the socio-technical and dynamic situation in which a team will be involved [6]. The system we choose to exemplify our work is the operating theater.

This digital collaborative environment represents with high fidelity its structure and its complexity. It allows controlled manipulations of the decision context and controlled information. It has been designed with game design mechanisms and interactive features to mimic professional activity. Each one plays the role of a professional with their own expertise field (such as surgeon, anesthetist, operating-nurse in an operating room). The participants must manage all together a real-life like professional and uncertain situation.

These situations should be designed to make teams understand the importance of non-technical skills and their impact on the way they manage the situation. The more they communicate, the more realistic their representation of the current situation should be. As a result, the most suitable decision should be made.

In others words, the challenge relates to provide a library of controlled educational situations where students are relatively free to act and can reproduce a causal chain of events that leads to virtual accidents.

So far, however, there has been little discussion about how designing a controlled and educational scenario to train staff to manage risk with real-life like situations.

Designing educational scenarios for risk management training is particularly complex because most of the time, the causal chain of events that leads to an accident is unpredictable. It implies a large variety of contributing factors, such as human factors and technical failures, which are difficult to combine artificially.

This paper aims to present a method to design such educational scenario for a virtual collaborative environment that particularly intents to train staff on risk management in a socio-technical a dynamic system. We focus particularly on risks connected to human errors such as communication default or non-suitable decision-making.

3 Approach

The online Oxford dictionary defines a scenario as "A written outline of a film, novel, or stage work giving details of the plot and individual scenes."

The online Cambridge dictionary defines a scenario as "a description of possible actions or events in the future" or ``a written plan of the characters and events in a play or film".

In the field of learning games, a scenario can be considered here as a set of elements: (1) a briefing (mission): presentation of the current situation and expected objectives to reach, (2) a virtual universe: objects, furniture, documents, characters… (3) a set of actions, pieces of information, documents, furniture and objects which can be manipulated throw the universe to achieve the mission, (4) playful and educational lockers such as educational prerequisites, educational failures to avoid… (5) educational skills to develop or acquire, (6) abstract or concrete concepts which can be manipulated with interactivity throw the environment: game play elements as inventory of assets, monetary system, virtual store\dots and educational concepts as programming, making decision… (7) steps or levels which compose the mission, (8) educational objectives to reach (visible or not in a briefing stage) (9) a debriefing: summary of outcomes with feedback that should help the player to succeed in the future.

Firstly, a scenario proposes to the players a short storytelling of what is the actual situation and what is the expected situation at the end.

Secondly, a scenario provides interactions that allow the players to achieve the mission and lockers (educational lockers or playful lockers) to prevent the player to succeed. Finally, outcomes are compared to expected objectives and results are immediately displayed at the end of a game session.

This definition particularly suggests that interactive storytelling triggers challenging opportunities in providing effective models for enforcing autonomous behaviors for characters in complex virtual environments. In other words, players should be able to be wrong, patch their errors, succeed or fail.

3.1 Challenges to design an interactive scenario for risk management

In the case of training environment for high graduated students, the classical challenge to design an interactive scenario consists in either (1) representing with creativity but also with high fidelity the professional environment through the virtual universe, (2) providing opportunities to characters to choose what they want to do, (3) providing interactions as part of the professional activity using objects/equipment/furniture/abstract elements arranged in the virtual universe, (4) giving relative but controlled freedom to act in the universe in order to compare with the expected behaviors.

In the case of training in risk management, different approaches exist such as training for emergency situations, improving the ability to identify and understand a critical situation and improve the situation awareness of a critical and risky situation [7] providing technical skills training on technical equipment with or without automation [8], providing maintenance training on dangerous equipment [9], training with exceptional/rare situations, training in a safety environment without any consequences in real life [10] …

We choose here to design educational situations to make teams able to identify and understand critical situations.

The library of educational situations must be composed of regular situations as well as critical situations in which deficiencies already exist or mistakes can be made and fix by the team.

3.2 Overview of methods to design a scenario

Three kinds of scenario can be listed:

- entirely controlled scenario: a script defines every possible paths to succeed or fail the mission.
- controlled scenario with a limited but real freedom: a large number of paths are possible to succeed or fail. As a consequence, none script defines all the possible combinations but algorithms can calculate them if necessary.
- entirely free scenario: machine learns from user's interactions and builds a statistically-realistic behavior. At the beginning, paths are unknown but machine learns from the user's experience over the time.

Designing an entirely controlled scenario consists in determining in details every available alternatives and their consequences in the virtual world. Such a scenario is called scripted or branching scenario. It can be graphically represented by a tree-like structure.

Each arc represents a choice and each node represents the state of the world. For every state, the user has to make a choice between different alternatives. There is normally one best choice, with the other alternatives being either wrong, or not as good. This kind of scenario offers different pipelines and maintains the user in an entirely controlled session.

We choose here the second method. The main argument that can be advanced to support this choice is that it offers a real-life-like experience even though the level of freedom is limited in a virtual world comparing to real-life. Despite of limited freedom, users should be free to manage a professional-like situation in a virtual world.

3.3 A method to design an educational scenario for risk management training

Designing scenarios based on real-life situation for risk management training consists both in (1) representing a perfect initial situation with competitive experts who made zero error before the team must manage the current situation and (2) representing an irregular situation where experts made mistakes that can lead to an incident if the errors are not tracked and fixed in time. If they are not fixed in time, problems will reveal as being part of the causal chain of events that leads to an adverse event. To that end, two categories of multi-player scenario have been designed.

The first one represents a regular situation embedded in a standardized scenario. It aims to train teams to apply safety recommendations and security process.

The second one represents an "irregular situation" embedded in a critical scenario. It aims to make team understand the interest of applying or adjusting policy safety procedure to avoid accidents. Designing such a scenario is more complex because it requires also analyzing the chronology of events before an accident and identifying the causal chain of events and their root-causes. The method described here has been inspired by the systemic method used to analyze real accidents that occurred in socio-technical and dynamic systems.

Basing our thoughts on systemic methods analysis, we designed "irregular situations" both dispatching failures or errors in an initial perfect situation and providing erroneous available issues during a decision-making or inappropriate tasks in the cloud of possible tasks.

The section 3.5 describes the Reason's Swiss model to represent the chain of events that leads to an accident. It helps to understand the method we use to design a scenario based on an ``irregular situation''.

3.4 Draw up an educational scenario based on standardized situation

Surgical interventions were recorded with four video cameras in the operating room. Analyzing these recordings, Devreux [11] studied how professionals communicate according to the level of experience they have.

The figure 1 illustrates the methodology used to design both an ideal pedagogical situation and an irregular pedagogical situation.

Firstly, we decide to specify the data using the Business Process Modeling and Notation graphical representation (BPMN).

"BPMN defines a Business Process Diagram (BPD), which is based on a flowcharting technique tailored for creating graphical models of business process operations. A Business Process Model, then, is a network of graphical objects, which are activities (i.e., work) and the flow controls that define their order of performance." [12].

BP Diagram enables us to represent parallel, synchronous and collaborative tasks as well as message transfer. This choice was also motivated by the necessary content validation step that must be done by interdisciplinary experts. In other words, it is easier to make experts validate contents with a simple graphical representation than with text-document or complex data files that are used by computer applications.

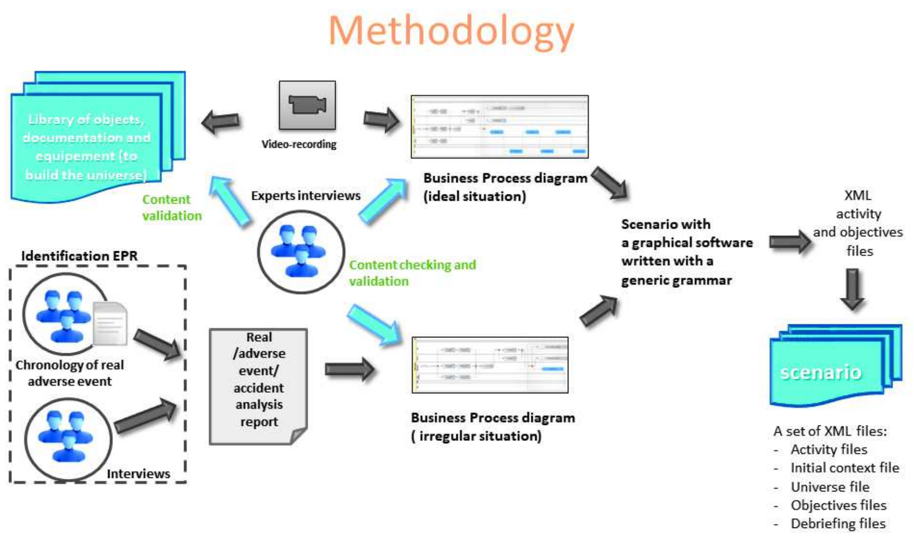

Fig. 1. Methodology used to design a risk management scenario based on an real surgery experiences.

However, the computerized human activity held in the BP diagrams cannot be used straightforwardly.

The computer can neither understand the interactions labeled on the activity nodes of the BP diagram nor relate them with their expected impact or meaning in the environment. The BP Diagram does not enable us to anchor the tasks to virtual objects on the virtual scene.

The process of anchoring the interactions into a semantic environment is another necessary step towards solving that problem.

As a result, we enhance BP diagram with a specific grammar to describe an educational scenario. This grammar enables us to anchor the tasks in the virtual environment and to increase the number of possible combinations for each character's role.

It uses predicates to combine sets of available tasks and pieces of information. As an illustration, the action "Wash hands" is no longer available if the action "put the surgical gloves" has already be achieved.

3.5 Draw up an educational scenario based on irregular situation

Extensive researches into disasters such as the disintegration of space shuttle Columbia [13], typically focus on the chains of events which caused these disasters. When such accidents are analyzed more closely, organizational problems, equipment breakdowns or loss of communication accuracy are often revealed as being part of the causal chain of events.

Different methods to analyze accidents and risks after slips happened exists. Some of them are based on systemic-based technique.

System-based technique methods are specially used for analyzing the causes of accidents that occurred in socio-technical systems.

Studying complex system, Reason [14] shows that most of the time, accidents result from multiple successive failures which could not have been corrected or stopped in time. Reason's model proposes that within complex systems, multiple barriers or layers exist to prevent accidents or errors. Mostly they do this very effectively, but there are always weaknesses.

Among the weaknesses, a poor communication between team members is often identified as an underlying factor of near-misses or accident.

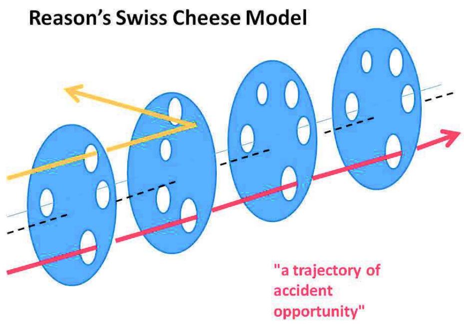

Fig. 2. The Swiss Cheese Model - Reason.

The Reason's Swiss Cheese Model represents the system as a whole. Each slice of cheese represents a barrier defense against failures and mistakes. The holes in the slices represent individual or collective weakness. The whole system is dynamic and the holes can vary in size and position on the slices as far as the situation evolves. The system can trigger accident when errors or mistakes are temporary aligned because none defense barrier can avoid the accident. As the result, when the holes in all slices are temporary aligned, they allow 'a trajectory of accident opportunity'.

Committing zero error is most of the time nearly impossible. However, it is possible to build defense barrier to detect mistakes and avoid unpredictable accident. The pursuit of greater safety is hindered by an approach that does not seek to remove the error provoking properties within the system at large. Advancing mistakes or identifying likely errors and then removing or correcting them before the accident would be a better way to improve safety.

Rasmussen who originally developed a part of risk management strategy [15]defines the performance of an activity with three levels: skill-based, rule-based and knowledge-based. Therefore, slips and fails can come from rules-based, skills-based or/and knowledge-based levels.

In this work, we will focus on skills-based and rules-based activity.

As a consequence, designing educational real-life situation for training consists in dispatching holes in a predefined situation and providing features that make team able to act, track and correct mistakes/failures using defense barriers.

The next section describes methods used to analyze the chain of events that leaded to an accident. It helps to understand the method we use to model educational feedback at the end of a game session.

Systemic analysis methods in healthcare. The idea that not only the disease but also the actors, teams, equipment, organizations, patient's profile\dots can ultimately be harmful to the patient is fairly recent in medicine. This new awareness dates from the 1990s and the report "To Err is Human" [16]. The same awareness has risen in France where the National Authority for Health (HAS) requires professionals to evaluate their practices through morbidity-mortality meetings. During these meetings, professionals declare and collect data on health care related adverse events.

To help practitioners through a rigorous and structured approach, the HAS recommends a systemic analysis method be used. The main two systemic analysis methods used to study near-misses or adverse events are ORION [17] and ALARM method [18].

Vincent [19] explains that analysis technique is not only a research for root-causes but "an attempt to look to the future". Methods help to reveal the weakness of the system and help to improve it.

Using ALARM for collaborative analysis of a real serious adverse event during a meeting help them to structure their approach.

When an adverse event occurs in the operating theater, the professionals involved organize a meeting to analyze the root causes with a view to proposing and implementing measures to improve practices. The analysis of the chain of events that leads to the adverse event is a collaborative task. The meeting takes place in a near future from the incident.

Before the meeting, a leader is in charge to prepare the meeting by finding out what happened and inviting to the meeting professionals who represent different trades.

During the meeting, they analyze the chain of events and try to find out a wide variety of contributing factors leading up to the studying incident.

During the morbidity-mortality meeting, professionals are supposed to propose improvement measures. These improvement measures have to be deployed in a relative short delay by a responsible identified during the meeting. After the morbidity-mortality meeting, a report has to be edited to the institution and particularly to the risk management staff.

The approach includes 6 stages: (1) collecting events that happened before and after the accident, (2) reconstituting the chronology of the event, (3) identifying shortcomings in care (defined in relation to standards for good practices) called factual analysis, (4) identifying their root-causes called systemic analysis, (5) proposing measures for improvement.

The systemic analysis which is supported by the French National Healthcare Authority is composed of 5 defense barriers: the patient, the actors, the team, the tasks, the environment, the institution and the organization.

When we designed a scenario representing an irregular situation, predefined anomalies were dispatched and hidden throw the barriers. Designers provide large variety of actions and pieces of information to create diversion. As the consequence, the anomalies are blended in a sea of pieces of information. Furthermore, some actions or decisions might launch an uncontrollable situation.

At the end, players are asked to identify what was wrong and what was right from their point of view.

The professional process from systemic methods has been reversed to force the students to identify their weakness and strengths.

4 Experiment and results

4.1 A case of study: the operating room

The educational content used to apply this method is based on real adverse events. These adverse events have common characteristics: a communication or decision making defaults have been identified as a contributing factor.

Less than 10 scenarios have been designed using the method described in figure 1. Training sessions have been organized using the learning game environment, which offers a library composed of standardized and critical scenarios. The experiments were carried out with the help of medical trainers and anesthetist-nurse trainers at the University Hospital of Toulouse. They aim to control how the students apply safety recommendations in real-life like situations. Lessons had already been delivered to the students on said topics prior to the experimentation and all the students had already worked in a real operating room during a professional internship.

This work is part of an innovative project named 3D Virtual Operating Room (http://3Dvor.univ-jfc.fr). It is a virtual multi-player digital environment which features a communication system that enable student to make synchronous collaborative decision. It allows controlled manipulations of the decision context and controlled information available to the subjects. It is composed of an operating room (medical equipment, patient record, drugs…) and avatars for the patient, the surgeon, the anesthetist and the nursing staff.

4.2 Results

During the experiment, computer data were logged; training sessions were video-recorded. Questions were asked the students on their game training experience through surveys (32 persons were concerned). Two scenarios were played. The first one presents a regular situation and the second one presents an irregular situation even though they seem to be similar. Both scenarios used in this experiment focuses on two adverse events: wrong patient's identity and wrong site surgery which should be avoided using the Surgical Safety Checklist recommended by the World Healthcare Organization. The two first checklist's items concerned are: “Is the patient’s identity confirmed?” and “Is the patient's operating site confirmed?”. The scenarios are divided into three steps: (i) Verifying patient's identity (ii) Verifying patient's surgical site (iii) Move the patient to the operating room. The scene takes place when the patient has been transferred from their room to the operating room. The mission assigned to the student’s team consists in preparing the patient from his arrival in pre-operating room until the end of the anesthesia procedure. The students are unaware of the hidden educational objectives that are: "Reducing the wrong patient risk applying the checklist", "Reducing the wrong side surgery risk applying the checklist" and “Adapting the security procedure to the context”.

Data logged were analyzed and presented in details by Pons Lelardeux et al. [20], [21]. Some results are mentioned below. Analyzing the topics of dialogue, the patient’s identity was the first topic of discussion or collected information and the operating surgery site was the second one. Different strategies were observed: the first one consists in collecting pieces of information from documents whereas the second one consists in collecting information asking questions to teammates. The debate related to moving the patient to the operating room was more often triggered than the others. The analysis of computer data logged revealed that the leader’s behavior during the decision making process is closely linked to the expert’s behavior. Relevant arguments placed by experts were able to inflect the decision of the leader whereas the lack of a relevant argumentation was the main root-cause of a disagreement.

For all teams, every deficiency (initially hidden and dispatched through the scenario) was found and exchanged between the team members. During the debriefing, they verbally expressed all the deficiencies found.

The data from the survey have been analyzed. 78 percent of players declare that the virtual environment is similar to a real operating theater. The figure 3 shows that the scenario designed using the model described in section 3.3 gives the feeling of learning. They mainly express that they feel free (even if the communication is restricted to bubble of information exchanges) to manage a real-life like situation. 72 percent of students declare that they feel perform learning safety process using such an environment. This particular result matches with the main goal of this typical multiplayer digital environment.

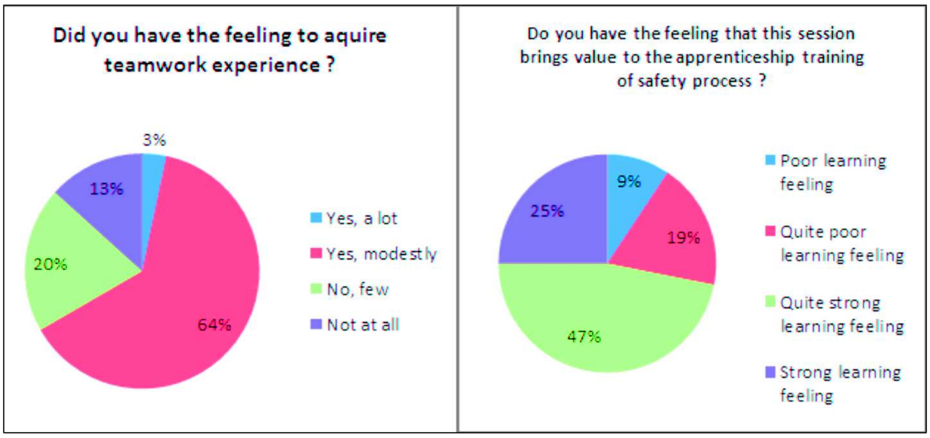

Fig. 3. Questions were asked to students about their feeling on the training session.

5 Conclusion

Training teams on risk management keeps up the interest of many companies in industry such as aviation, nuclear, healthcare… as they work in dynamic and unpredictable contexts.

One of the critical point is to create educational and entirely controlled training environments that support providers to train staff to improve their teamwork performance making them understand the importance applying or adjusting safety recommendations. In this article, we presented a method to design multi-player educational scenario for risk management in socio-technical and dynamic context. This method has been inspired by the systemic method used to analyze real accidents. A dozen of scenarios in the healthcare field have been designed using this method. Training sessions have been organized using the learning game environment with standardized and critical scenarios designed using this method. Experiments were carried out with trainers and their students at the University Hospital of Toulouse. They aimed to analyze student's behaviors facing to a real-life like professional situation. Data analysis shows the different strategies used by the teams facing to a regular or unexpected situation. The experiments allow identifying discrepancies on what must be done if such a case happens. Most of the time, team members found contradictions and hidden anomalies. It was the starting point to trigger debates on what must be done. The results confirm that the method employed to design risk management educational scenario works. Educational scenarios designed with this method support teams to experiment with relative freedom a real-life like professional situation.

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The experiment described has been conducted with the collaboration of C. Paban, M. Domec and C. Martin who are trainers at the University Hospital.work.

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