Towards a Grid for Characterizing and Evaluating Crisis Management Serious Games: A Survey of the Current State of Art

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ABSTRACT

Over the last few decades, interest has grown in the use of serious games (SG) and their assessment in almost every sector. A privileged application domain of SG is crisis management (CM) in which these tools improve crisis behavior and/or management in a safe environment while reducing training costs. However, it is difficult to characterize and evaluate such specific SG. This article proposes a comprehensive grid defining features for description, analysis and evaluation of Crisis Management Serious Games (CMSG). First of all, the authors introduce SG, CM as well as evaluation and assessment concepts, and discuss their particular challenges by highlighting the need of using assessment and evaluation techniques to support learning and/or training. Then, the authors present, classify and compare the most relevant techniques dedicated to address this need by encompassing the state of the art of learners' assessment and evaluation approaches used in CMSG. Finally, this article presents in detail the proposed grid and discusses the major findings and contributions.

KEYWORDS

Characterization, Crisis Management, Evaluation, Grid, Learners' Assessment, Serious Games, State of the Art

1. INTRODUCTION

In the last few years, the increasing use of Information and Communication Technologies (ICT) has offered a new horizon for using simulation and gaming as methodological tools for an effective learning /training (Walker et al., 2011). Nowadays, considerable attention has been paid to a new class of games called "Serious Games" (SG) which was created for training or educational purposes rather than pure entertainment (Alvarez, 2007). Thanks to their approach combining seriousness and fun as well as the interesting and useful opportunities they provide (interactivity, immersion, simulation, etc.), they have become very powerful and popular learning devices (Boughzela, 2014). The main

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goal of the SG is to make the knowledge and/or competencies acquisition more effective in a wide range of sectors including defense, communication, education, and health by increasing the learner motivation and engagement while playing.

Crisis Management (CM) is exemplar as an application domain where SG development has grown exponentially and thus has been the object of numerous research studies in serious games area (Di Loreto et al., 2012a). CM popularity resides in exploring different types of crisis (natural disasters, terrorist attacks, nuclear or industrial accidents, etc.) each involving multiple roles (firefighters, medical first responders, police, civil protection, etc.) and collaborative behaviors (evacuation, victim salvation, decision process, etc.) (Daoudi et al., 2017). Serious games for crisis management (CMSG) are considered as a new alternative training approach to teach workers different kinds of skills (technical and/or soft) and to train them to manage emergencies in an engaging way (Di Loreto et al., 2012a).

In the literature, several research works have been proposed to assess and/or evaluate learners-players using various techniques in individual and/or collaborative training contexts of crisis management. They focus on different evaluation criteria such as:

- Learning aspects covering competencies/skills (Oulhaci et al., 2015), and knowledge (Silva et al., 2014; Anita et al., 2015; Mendez et al., 2009);
- Emotional aspects including stress, fear, and panic (Mora and Divitini, 2014; Nguyen et al., 2014);
- Social aspects consisting of coordination (Theo Ovan et al., 2015), cooperation (Di Loreto and Divitini, 2013), and communication (Haferkamp et al., 2011; Di Loreto et al., 2012b).

All these studies show a growing interest to CMSG in improving and supporting both technical and soft skills. This growing interest is followed by an increasing need to identify the characteristics (descriptive features) and the common evaluation criteria (success factors) in order to compare them and to measure their effectiveness for learning. Meeting this need requires specific aspects and principles that can be validated and applied by domain experts and/or evaluators in order to characterize and evaluate the success of serious games environments for crisis management training. Considerable efforts and publications are currently being devoted to researching and evaluating CMSG, thereby increasing both the quantity and the quality of such evaluations (Oulhaci et al., 2015; Haferkamp et al., 2011; Theo Ovan et al., 2015; Carole et al., 2016; Silva et al., 2014; Sooraj et al., 2016; Di Loreto et al., 2012b; Anita et al., 2015; Mendez et al., 2009; Tena-Chollet et al., 2016). Considerable weaknesses remain, however, including the following:

- The absence of comprehensive classification for comparative evaluation techniques used in CMSG.
- The absence of an evaluation analysis grid for characterizing and evaluating CMSG.
- A lack of implicit ("stealth") techniques for data-gathering and assessment in CMSG.
- A lack of works considering both emotional and social aspects in evaluating collaborative CMSG.

In short, despite a promising increase in methods and findings, we continue to lack a classification of evaluation/assessment techniques used in CMSG as well as an overarching an evaluation analysis grid for describing and evaluating such environments. In this perspective, this article tries to bridge these two main research gaps by building a new classification of evaluation/assessment techniques in CMSG and a new Grid of criteria for Characterizing and Evaluating Crisis Management Serious Games (G-CE-CMSG). The classification aims to present and classify the most existing techniques

and methods utilized for assessing and/or evaluating learners during a training session based on a particular CMSG. The grid aims to gather information on the characteristics of CMSG and to identify their success factors in order to maximize their use. Indeed, the defined elements in the proposed grid should be taken into account while developing a novel technique for assessing and/or evaluating learners during their interactions with a given CMSG.

The remainder of this article is organized as follows. Section 2 overviews some background knowledge on SG concept, CM domain as well as assessment and evaluation processes. Section 3 resumes the analysis of the most recent existing works in CMSG evaluation and presents a survey including several serious games designed for crisis management training. Section 4 describes the proposed G-CE-CMSG and details its principal elements. Section 5 discusses our major findings and contributions. Section 6 concludes the article and outlines our future research directions.

2. BACKGROUND

The aim of this section is to give an outline of the key concepts and terminologies used in the rest of this article concerning SG concept, CM domain as well as assessment and evaluation processes.

2.1. Serious Game

Today, serious games, also called game-based learning, have gained undeniable popularity since societies and institutions decided to implement them as part of their training programs (Boughzela, 2014). A survey in the world of serious games has provided a wide range of definitions.

The first formal definition of the concept was introduced by (Abt, 1970). In his book, Abt gives a clear definition of serious games: "Games may be played seriously or casually. We are concerned with serious games in the sense that these games have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement. This does not mean that serious games are not, or should not be, entertaining." In recent years, (Michael and Chen, 2005) defined serious games as: "Games that do not have entertainment, enjoyment or fun as their primary purpose". (Zyda, 2005) defined this concept as: "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." According to (Alvarez, 2007), a serious game is: "A computer application, whose original intention is to combine with consistency, both serious aspects as, but not limited to, non-exclusive, teaching, learning, communication, or information with playful springs from the video game."

To summarize according to the variety of definitions, we can say that serious games are games in which learning is the first purpose. These games are designed to create a skill development environment for the learner-player while retaining the same focused motivation context of "fun" games (Alvarez, 2007). The definitions cited above have allowed us to highlight the most important properties of this tool:

- It maintains balance between keeping game-play fun on the one hand and learning aspect on the other hand
- It targets multiple learning objectives such as teaching, training, educating and raising awareness about special issues
- It is used in numerous areas like health, education, defense, military, emergency management, politics, advertising, business
- It is intended for all age groups including children, adolescents, adults and older people

In a learning/training context, all these following concepts: gamification, serious games, and simulation games aim to learn/train users to develop a particular competence in a particular domain

supported by a computer-based learning environment. However, there are some differences between them according to the gameful design. In fact, gamification is the application of game elements in a non-game context (the final learning environment is not a game). Serious games are indeed games aiming to learn about developing a particular competence by focusing on "game-play rules" to follow. Simulation games can be considered as a sub-category of serious games that simulate a real-world scenario of learning: they are game environments which recreate a learning/training situation that occurs in real life (Callies et al., 2017).

The presented work can be applied in serious games as well as simulation games for crisis management training.

2.2. Crisis Management

Disasters are more and more a recurrent phenomenon and may be extremely damaging (Di Loreto et al., 2012a). They are extremely harmful since they threaten people's lives (deaths, injuries, diseases, etc.) and heavily affect the economy. The increasing crisis frequency and the growing damages require effective crisis management processes in order to ensure prompt and effective response as well as reduce losses under stressful and critical conditions (Sagun et al., 2009). Crisis management can be defined as the application of strategies designed to help an organization, its stakeholders, or the general public deal with an unexpected and significant negative event (Walker et al., 2011).

The aim of crisis management is to be well prepared for crisis and to ensure a rapid and adequate response to the crisis situation. Crisis response and management is a process involving different types of competencies, from very specific technical procedures to soft skills. It involves also different kinds of workers from different organizations (medical unit, police, civil protection etc.) having to work simultaneously and in a hurry to reach their common goal consisting in crisis reduction (Di Loreto et al., 2012a). The existing crisis situations are commonly classified into three main categories as follows (Sagun et al., 2009):

- **Natural Disasters:** Are disasters resulting from natural hazards that threaten human life, property, and the environment itself such as earthquakes, hurricanes, forest fires, and floods.
- **Human-Made Disasters:** Also called as man-made disasters, are disastrous events caused by humans, i.e. terrorist attacks and pollution.
- **Technological Crises**: Are disasters caused by human application of science and technology like industrial accidents, oil spills, cyber attacks, and airplane crash.

In order to combat crisis and to go back to normal state in a quick and effective manner, every organization should have a crisis communication team, composed of key emergency actors, who should apply all the phases of CM process. In general, the CM process involves the following actions (Sagun et al., 2009):

- **Preparedness Phase:** In this stage, members of emergency team should identify the needs and requirements of mitigation as well as threats and possible consequences of the crisis situation.
- **Response Phase:** During the response stage to the situation, members of emergency team should recognize the seriousness of the problem in order to generate an appropriate response; they should apply their technical expertise and social skills to save human life, and to help meet victim's physical and mental needs.
- **Recovery Phase:** The final stage of CM process is when things begin to return to normal state; members of emergency team should train to generate new solutions as well as to reconstruct destroyed buildings and infrastructure in order to develop stronger resistance to any future disasters.

Crisis and disaster training is a highly complex and costly task that requires sophisticated training approaches such as training materials, coaching, and debriefing sessions (Sagun et al., 2009). Recently, a new alternative learning approach called "Serious Games" has emerged to represent an ideal tool for teaching workers different types of skills in an engaging way (Walker et al., 2011). Serious games for crisis management offer an interesting complement to traditional training, as they are very useful training tools for people, both civilian and emergency actors, who have to manage a crisis. They have the potential to develop both technical skills (expertise and knowledge for applying emergency operating procedures) and non-technical skills (also called soft skills or best practices like communication, coordination, and stress management) under pressure for individuals and teams (Di Loreto et al., 2012a). Besides, CMSG are developed in order to raise awareness and consciousness about the most relevant problems linked to the CM domain. The use of serious games to teach concepts related to the field of emergency management not only provides a cost-effective, time-saving alternative, it allows an optimal learning by bridging together theory and practice in a simulation environment (Sooraj et al., 2016).

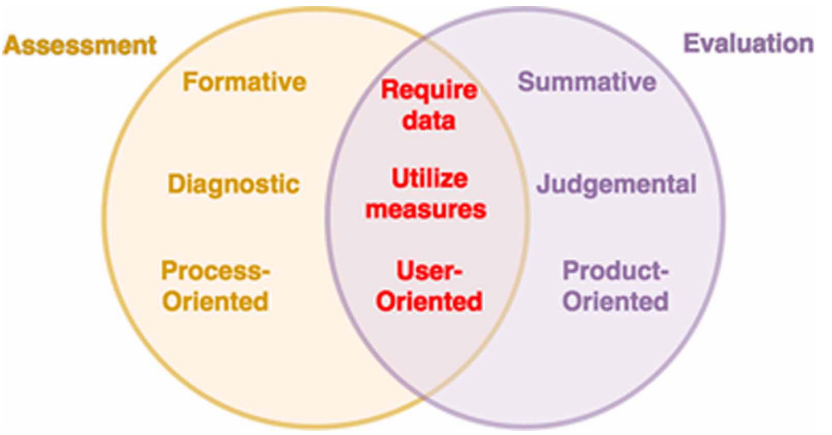
2.3. Evaluation and Assessment

In this sub-section, we define differences and similarities between the two terms "Assessment" and "Evaluation" in a learning context, and we show the need of research works in CMSG evaluation.

Both assessment and evaluation require (qualitative and/or quantitative) data about learners and utilize (direct and/or indirect) measures to understand, analyze, and evaluate learners' behaviors during a learning session (Daoudi et al., 2017). Assessment is defined as a process of collecting and interpreting data about learners in order to provide them feedbacks on their failures and progress and to make then improvements of their current performances. However, evaluation aims to make judgments/conclusions about serious game effectiveness and usefulness for learning on the basis of a particular set of criteria (Bellotti et al., 2013; Petri and Wangenheim, 2016; All et al., 2015).

For more clarity, assessment can be described as a "formative" measurement implemented throughout the entire learning process for the purpose of diagnosing learners' actions/activities and identifying areas of improvement to increase learning quality (Daoudi et al., 2017). Evaluation is a "summative" (final) assessment conducted at the end of a learning process in the purpose to test the overall learners' achievements and to draw judgments about learning quality (Daoudi et al., 2017). So, we can conclude that assessment is concerned with learning process, while evaluation focuses on the product (the learning environment). Figure 1 summarizes the key differences and similarities between assessment and evaluation.

Figure 1. Assessment Vs Evaluation



Despite the differences between these two terms, the utilized techniques to analyze learners' behaviors while playing can be used for both assessment and evaluation purposes. For this reason, we will consider, in the rest of this article, that "assessment" and "evaluation" can be associated together according to the used techniques.

The growing interest for crisis management serious games has raised particular needs in terms of learners' assessment and evaluation (Oulhaci et al., 2015). Learners' assessment in CMSG represents actually an important research subject that often relies on "human" post-game debriefing based on logs analysis, questionnaires or interviews. In fact, the learner's assessment is performed manually either by the learner itself (which we called self-assessment) or by human monitors (Oulhaci et al., 2015). In addition, producing a collective assessment in this kind of SG, especially in collaborative CMSG, remains a difficult task; that's why the assessment of the collective performance is not enough addressed in the literature and relies on the experience of individual game players (Oulhaci et al., 2015). However, it looks very important to produce a collective assessment of a particular CMSG since it contains global and useful information about the game effectiveness for training. Moreover, it should be noted that the carried-out evaluations in the field of CMSG consider in most cases competencies and knowledge acquired by players during a game session without exploiting their emotional and social states in the evaluation process (Daoudi et al., 2017). Therefore, the issue of assessing, both individually and collectively, emotional, social and cognitive states of learners-players is not yet studied. All these aspects constitute a big challenge and need to be addressed in future research working in this area.

The next section aims to report the most interesting works published in the domain of learners' assessment and evaluation in crisis management serious games.

3. LEARNERS' ASSESSMENT AND EVALUATION IN CRISIS MANAGEMENT SERIOUS GAMES

This section focuses on learners' assessment and evaluation in CMSG and offers a survey of state of the art of assessment techniques to support learning/training. Then, we provide a classification of the current techniques used in CMSG, through which, we hope to contribute in the future research in the area of CMSG evaluation.

3.1. Classification of Learners' Assessment and Evaluation Techniques

Until now, there are numerous research studies published in the domain of learners' assessment and evaluation in CMSG. In this article, we propose to classify the most existing recent studies into two main approaches in relation with the technique type used in evaluation/assessment process. The first approach gathers all techniques that assess learners-players explicitly like questionnaires (Haferkamp et al., 2011; Silva et al., 2014; Di Loreto et al., 2012b; Anita et al., 2015) and sensors devices (Mora and Divitini, 2014). The second approach focuses on techniques that assess learners using Artificial Intelligence (AI) models and methods such as data mining and big data analytics (Zagorecki et al., 2013; Yi et al., 2011; Emmanouil and Nikolaos, 2015), as well as multi-agent systems (Oulhaci et al., 2015). The main difference between explicit and implicit approaches is related to the ways of collecting and analyzing data about learners (Daoudi et al., 2017). On the one side, an explicit approach aims to use direct and obvious measures of collecting and analyzing data about learners. Therefore, this approach requires human intervention outside the SG in order to collect data and give an assessment of learners' behavior during playing. On the other side, an implicit approach aims to collect and to analyze data about learners in an indirect and unobtrusive way, without disrupting the high level of engagement provided by SG. Hence, an implicit approach of learners' assessment is integrated in the SG, and does not require any human intervention.

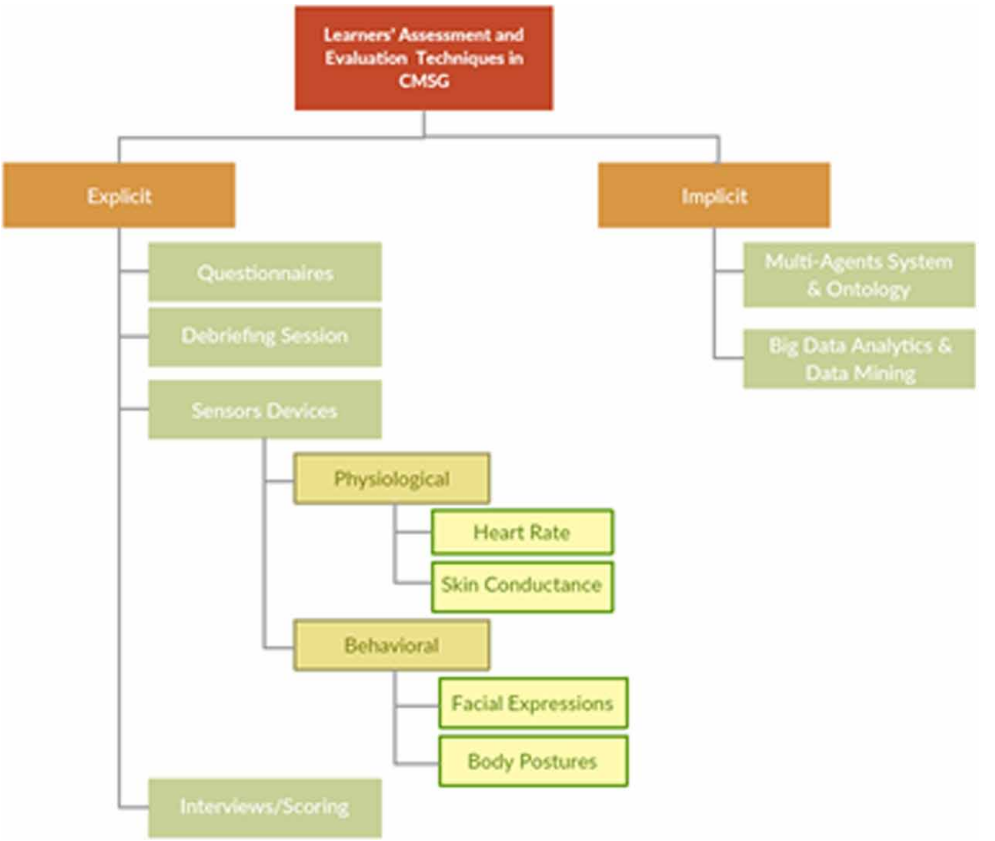
3.1.1. The Proposed Classification

In this section, we propose a new classification of learners' assessment and evaluation techniques in CMSG. Figure 2 presents the organization of the key aspects that constitute our classification.

As previously explained, learners' assessment and evaluation in CMSG can be achieved explicitly or implicitly. The explicit assessment can be accomplished using a questionnaire, an interview, a debriefing session or some sensor devices. In fact, self-report questionnaires (Haferkamp et al., 2011; Silva et al., 2014; Di Loreto et al., 2012b; Anita et al., 2015) are frequently employed because they are simple and easy to implement, but they represent a subjective assessment that rely on non-exhaustive players opinions (Daoudi et al., 2017). In addition, questionnaires disrupt the high level of engagement provided by SG since they require stopping the learner from playing and requesting him to answer some questions. Moreover, the use of hardware devices and equipments provides an explicit way to assess the learner while interacting with SG environments (Mora and Divitini, 2014). This technique is based on sensors providing quantitative information describing behavioral and/or physiological learners' reactions. In this context, data is captured in real time without stopping the learner's playing and it is easy to manipulate and to analyze. However, it obviously requires the use of additional sophistical hardware and software equipment that can be expensive (Daoudi et al., 2017).

Learners' assessment can also be achieved implicitly. This is realized by exploiting the techniques of artificial intelligence in order to analyze and assess the behavior of learners while they play SG. In this context, we can cite big data analytics and data mining techniques (Zagorecki et al., 2013; Yi et al., 2011; Emmanouil and Nikolaos, 2015), as well as multi-agent systems

Figure 2. Classification of Learners' Assessment and Evaluation Techniques in CMSG



and ontology (Oulhaci et al., 2015). All these techniques have the major advantage of adopting implicit models and methods of AI for learners' assessment without affecting the high level of engagement provided by SG. So, this type of assessment is intended to support learning, maintain motivation, and increase learners' engagement in the virtual word of the game. However, such implicit techniques represent the problem of validation and reliability of their results compared to explicit techniques. In fact, implicit techniques using artificial intelligence algorithms require a set of measures able to quantify the accuracy and consistency of their obtained results in order to validate them. For example, machine learning based techniques designed to evaluate learners' sentiments and emotions are considered as valid and reliable techniques if they produce accurate and consistent results compared to those extracted from sensors devices.

3.1.2. Explicit Techniques of Learners' Assessment and Evaluation in CMSG

This section identifies techniques that have already been used to assess the learner behavior explicitly. We present essentially self-report questionnaires, sensors devices, and debriefing sessions.

- **Self-Report Questionnaires:** Learners' assessment can be performed through assessing the learners' answers to a questionnaire (or an online survey) at the beginning (Silva et al., 2014; Anita et al., 2015), during or at the end of a game-based learning session (Silva et al., 2014; Anita et al., 2015; Haferkamp et al., 2011). For example, (Haferkamp et al., 2011) presented an assessment of the "DREAD-ED" (Disaster Readiness through Education) game for training of social skills including communication, teamwork, emotional intelligence, and group decision making in a crisis situation. The assessment process was performed via a questionnaire using a 5-point Likert scale measuring, on a quantitative level. In this process, the thoughts and learner opinions on the training session are combined with qualitative data obtained from the tutor's interview during game play. Based on this combination, the authors can conclude whether the game contributes to the learning of social skills. Moreover, (Silva et al., 2014) invited children from 10 to 13 years, residents of the city of Rio de Janeiro in Brazil, to use the serious game "Stop Disasters" in order to build a safety culture for emergencies. To analyze and assess learners' performances and to verify if the game really improves the awareness of risky situations, the participants answered questionnaires before and after playing the game about three main aspects namely game-play, missions, and game scenarios.
- **Sensors Devices:** Advances in the branch of neurosciences have led to the development of various equipment and hardware devices able to continuously detect and recognize human emotions via facial expressions, body postures, speech, and physiological signals (Daoudi et al., 2017). Several works have shown that these measures can provide an indication of learners' emotions. For instance, (Mora and Divitini, 2014) showed the usefulness of collecting data from the WATCHiT sensor during a training event to support debriefing in the crisis management and preparedness field by addressing two different scenarios CroMAR and Procedure Trainer. CroMAR supports disaster managers during in-situ debriefing after large events, whereas Procedure Trainer supports a team in reflecting after the simulation of a medical emergency procedure. This debriefing based on sensor data is considered as a form of assessment with explicit attention to emotions as well as ideas and behaviors of learners.
- **Debriefing Sessions:** Learners' assessment can be performed also through a debriefing session after the training process. Many works in CM context have shown that this technique, referring to a conversational session, revolves around the sharing and examining of information after a crisis event has taken place (Tena-Chollet et al., 2016; Haferkamp et al., 2011). Indeed, a debriefing process can serve a variety of purposes. For example, these sessions can be used for analyzing the critical aspects linked to the intervention, reporting/discussing individual and collective performances of players, understanding their misconceptions/errors, or learning from experience (Di Loreto et al., 2012a).

3.1.3. Implicit Techniques of Learners' Assessment and Evaluation in CMSG

In this section, we present implicit techniques that have been used in the literature to assess the learner during the interaction with a CMSG. These techniques are based on specific artificial intelligence models and methods. We present essentially assessment techniques based on multi-agent systems combined with an ontology as well as big data analytics and data mining techniques.

- **Multi-Agent Systems Combined with Ontology:** Learners' assessment while playing a serious game can be supported by the agent technology. For example, (Oulhaci et al., 2015) presented a multi-criteria and distributed assessment approach of learners in a collaborative context illustrated with the "SIMFOR" SG dedicated to crisis management. In this purpose, they started by proposing a methodological framework for learners' assessment which is based on the concept of Evaluation Space allowing the production of individual and collective assessments and targeting the management of distributed and heterogeneous information (Oulhaci et al., 2015). In order to implement this methodological assessment framework, they developed an agent-based architecture permitting to improve Non-Player Character (NPC) adaptability and to support individual and collective learners' assessment. In fact, the authors use multi-agent systems to develop software agents simulating the behavior of human players (learners) and virtual players (NPC). Thanks to the BDI model (Beliefs, Desires, Intentions), these agents are designed to collect data about learners, and assess their behavior during the game session (Oulhaci et al., 2015). All knowledge used or produced by the assessment module is stored as ontology in the domain model and the learner model. The domain ontology describes the general concepts of crisis management domain but adapted to the SIMFOR context like procedural knowledge, and environment entities (actors, disaster, infrastructure, etc.). The learner ontology, instantiated for each learner-agent, represents his mental state at a time *t*. Although the interest of this assessment process, the authors did not consider emotional states of learners during their activities. Indeed, emotions play an important role in CM training and should be taking into account during learners' assessment in order to produce a complete analysis.
- **Big Data Analytics and Data Mining:** Recent works in the field of disaster and crisis management applied data mining and big data analytics techniques to assess and support the group decision-making as an important factor of soft skills (Zagorecki et al., 2013; Yi et al., 2011) (Emmanouil and Nikolaos, 2015). For instance, (Yi et al., 2011) exploited these techniques to automatize analysis and assessment of large volumes of collected data from heterogeneous sources in different phases of CM in order to assist decision-making process. They gathered different types of data (quantitative or qualitative, structured or unstructured, static or dynamic) produced in a crisis situation in order to identify useful patterns and to extract relevant knowledge about the considered incident. In fact, during a crisis situation, the responsible workers must quickly make decisions (Yi et al., 2011). The quality of these decisions depends on the quality of the available information. An objective, comprehensive, and accurate assessment of the situation can empower decision-makers during a crisis to make convenient decisions, take suitable actions for the most affective crisis management (Yi et al., 2011). Therefore, the goal of the data mining process is to help decision-makers understand characteristics of emergencies, select the appropriate alternative, and predict what will occur in the future by analyzing available crisis information using a collection of data mining functions.

3.2. Survey on Serious Games Applied to Crisis Preparedness and Management

In recent years, several serious games in particular simulation games have been developed to achieve crisis preparedness and management. Experiments on their usage have shown that games can help to address some of traditional training limitations (Di Loreto and Divitini, 2013). In this section, we provide an overview of some existing serious games designed for crisis management training. Since

we are interested to CMSG evaluation and assessment, we describe in the following serious games which have been subject of evaluation works using interesting techniques.

- **SIMFOR (Simulation and Formation) (Oulhaci et al., 2015):** Is a multi-players serious game for crisis management training allowing different people (specialists of the field and non-professionals) to learn different skills (shared or specific) in the same game session. The objective of this game is to create a training environment that immerses users in a real scenario of crisis management situation.
- **FloodSim (Mendez et al., 2009):** Is a free online game aiming to raise awareness about flooding danger in the United Kingdom and to increase citizens' engagement through an accessible simulation. The goal of the game is to train people of the United Kingdom how to protect from floods that damage the economy and threat their lives.
- **SPRITE (Participatory Simulation of Territorial Risks) (Carole et al., 2016):** Is a serious game placing the player (population or elected representative) in the role of a decision maker and letting him explore various policies in order to raise his awareness about coastal flood risk on the Oleron Island. SPRITE has a double pedagogical mission: informing the player about a major but often under-estimated risk (coastal flood); and forcing him to reflect on policies for managing this risk.
- **Stop Disasters! (Silva et al., 2014):** Is a free online game designed to raise awareness of natural disasters' significant impact and to explain simple precautions that can save lives. The game teaches families the skills needed to manage natural catastrophes like earthquakes, tornadoes, hurricanes, and floods.
- **DREAD-ED (Disaster Readiness through Education) (Haferkamp et al., 2011):** Is a collaborative serious game that enables crisis units to train soft skills (communication and group decision-making) in a virtual environment. The game places its users in a crisis management team that is dealing with an evolving emergency (a huge fire close to a chemical park). The game aims to encourage its users to critically reflect on their decisions made within the game and to train communication in stressful situations.
- **Serious Game on Incident Management Frameworks for Post Disaster Management (SGIMFPD) (Sooraj et al., 2016):** Is a multi-players serious game that teaches communication and collaboration concepts during post-disaster operations in a safe and secure training environment. The game present two essential concepts for effective post disaster management: Rapid Damage Assessment and Incident Management System. The game can also be used as a tool to increase community preparedness by teaching villagers an effective disaster response.
- **Don't Panic (Di Loreto et al, 2012b):** Is a cooperative board game designed to enhance soft skills for civil protection workers in the crisis management field. The game (1) adds the fun element to training about stressful situations linked to panic management and (2) teaches social skills such as communication, team management and coordination.
- **B-SaFe! (Anita et al., 2015):** Is a multi-players board game designed to increase citizens' awareness of man-made and natural risks and to give them considerations on how to prepare for and react to a broad range of adversities.
- **CRISIS-SIM (Tena-Chollet et al., 2016):** Is a serious game for decision-makers facing up a major crisis. The game aims to train all the skills necessary for emergency management through the decision-makers' experience consisting of: anticipation, communication, cooperation, stress management, decision-making, and strategic steering.

For more clarity, the main characteristics of the previously described CMSG are recapitulated in Table 1.

According to Table 1, we can easily note that the most analyzed serious games have been assessed using explicit techniques especially pre/post questionnaires, interviews and debriefing

Table 1. CMSG summary

Serious game	Multi-actors	Targeted-audience	Crisis type	Trained skills	Evaluation/Assessment techniques
SIMFOR	Yes	General public	Escapement of toxic products after a traffic accident	Procedural knowledge	Multi-agents system & ontology
Stop Disasters!	No	General public	Earthquake, flood, hurricane, wildfire, tsunami	Declarative knowledge	Pre/post questionnaires
DREAD-ED	Yes	Professionals of domain	Flood	Social skills	Debriefing session & questionnaires
FloodSim	No	General public of United Kingdom	Flood	Declarative knowledge	Feedback left on the site & telephone semi-structured interviews
SPRITE	No	General public of Oleron island	Flood	Procedural knowledge	Scoring
Don't Panic	Yes	Civil Protection experts	All type of accidents	Soft skills	Interviews
SGIMFPD	Yes	General public	Earthquake	Technical & soft skills	Scoring & Bloom taxonomy
B-SaFe!	Yes	Students	Natural and man-made risks	Declarative knowledge	Pre/post questionnaires
CRISIS-SIM	Yes	Specialists of domain	Flood, traffic accident for the transportation of hazardous materials	Technical & soft skills	Debriefing session & sound and video recordings

sessions. For example, Stop Disasters! game, B-SaFe! game and DREAD-ED game were assessed based on questionnaires aiming to collect information about learners' behavior and knowledge during a game session. Furthermore, serious games Don't Panic and FloodSim were assessed via qualitative interviews in order to report thinking, emotions, attitudes, and perceptions of players during playing. The analysis shows that despite its limits, the most used explicit technique is assessment via questionnaires. Table 1 shows also that a limit number of serious games have used implicit techniques to obtain learners' assessments. For instance, the serious game SIMFOR integrates a multi-agent architecture in order to produce both individual and collective assessments.

The following section presents our main contribution consisting in the proposition of an evaluation analysis grid for characterizing and evaluating crisis management serious games.

4. TOWARDS A GRID FOR CHARACTERIZING AND EVALUATING CRISIS MANAGEMENT SERIOUS GAMES

The state of the art carried out in the domain of CMSG evaluation showed that there is no evaluation grid designed especially to CMSG. To fill this research gap, we developed an evaluation analysis grid based on a list of CMSG success features. This grid will be the base of a theoretical framework for characterizing and evaluating CMSG. In this section, we begin by giving a general description of the proposed grid. Then, we present in detail its structure as well as its main elements.

4.1. Overview of the Proposed Grid

Our research aims to characterize, analyze and evaluate CMSG to improve them and to maximize their effectiveness. In the field of SG, effectiveness is defined as "…the successful attainment of its intended goals under real-world conditions to maximize its external validity…" (All et al., 2015). Our contribution entitled G-CE-CMSG (Grid for Characterizing and Evaluating Crisis Management Serious Games) is inspired by studies focused on criteria used to evaluate the effectiveness of digital game-based learning (All et al., 2015) (Bedwell et al., 2012) and to assess the use of serious games in higher education (Boughzela, 2014). The proposed grid is useful to assist and support CMSG evaluators or domain experts in verifying the effectiveness of a particular game for training skills.

On the one hand, the proposed grid allows characterizing the serious game by defining a list of descriptive features like game nature (single-player or multi-players), crisis type (natural or human-made), trained skills (technical and/or soft), game genre (digital or non-digital), and targeted audience (professionals, general public, etc). On the other hand, the grid allows the evaluation of CMSG basing on different learners' aspects including emotional, social and cognitive states. These aspects are deduced from both learning and game mechanics of the serious game (Bedwell et al., 2012) and are applied in a crisis management context. In short, the proposed G-CE-CMSG provides a classification scheme that could be considered as a descriptive and evaluation tool by giving qualitative information to describe some characteristics of the game and to judge if it is effective to use. Table 2 gives a synthetic view of the G-CE-CMSG.

4.2. Detailed Description of the Proposed Grid: Structure and Selected Criteria

In order to ensure a logic structure of the proposed grid and to facilitate its readability, we propose to divide it into two main themes including several analytical criteria. These themes provide a rich support to both characterize and evaluate the success of a given serious game for crisis management training.

Table 2. Grid-Characterization Evaluation-Crisis Management Serious Games (G-CE-CMSG)

CMSG Characterization	
Multi-Actors: individual or collaborative	
Targeted Audience: professionals, students, children…	
Scenarios Number	
Crisis Type: natural disaster, man-made, or technological	
Trained Skills: technical skills, soft skills	
Game Genre: digital game (online, mobile…) or non-digital game (board, card…)	
Success Factors to Evaluate the Effectiveness of CMSG	
Training Outcomes Deduced from Learning Mechanics	**Social & Emotional Outcomes Deduced from Game Mechanics**
Competencies	**Social Outcomes**
Declarative Knowledge	Communication
Procedural Knowledge	Coordination and Roles
Conditional Knowledge	Cooperation/Collaboration
Cognitive Strategies	Group Decision-Making
Knowledge Organization	**Emotional Outcomes**
Application	Stress Management
	Fear/Panic Management

The first theme, called "CMSG Characterization", gives a brief description of the SG. It is composed of a set of the most important criteria used to describe the characteristics of SG and consisting of:

- **Multi-Actors:** Individual or collaborative;
- **Crisis Type:** Natural, technological or man-made;
- **Trained Skills:** Technical and/or soft;
- **Scenario Number**;
- **Targeted Audience:** Professionals, general public, children, students, etc.
- **Game Genre:** Digital (stand-alone, online, mobile, etc.) or non-digital (board, card, etc.)

The second theme contains all relevant common criteria used to evaluate the success of a given CMSG for learning/training. This theme, called "Success Factors to Evaluate the Effectiveness of CMSG", is divided itself into two sub-themes according to two types of desired outcomes. For each sub-theme, different sub-components are showed. In fact, we suggest distinguishing two categories of outcomes that should be considered when evaluating CMSG consisting of training outcomes as well as social and emotional outcomes. For these outcomes, several criteria must be used. In the rest of this sub-section, we present in detail each outcome cited above:

- **Training Outcomes Deduced from Learning Mechanics:** The most crucial element required to measure the effectiveness of a particular SG is the achievement of the training/learning goals fixed by the game-designer/developer (All et al., 2015). Particularly in CMSG context and basing on research works in Intelligent Tutoring Systems (ITS) (Oulhaci et al., 2015), training outcomes, representing the cognitive state of learner, are primordial to evaluate the success of a given CMSG. They include several learning aspects deduced from relevant pedagogical resources of the serious game called "learning mechanics." By learning mechanics, we mean the adopted pedagogical techniques to present different training outcomes such as competencies, declarative knowledge, procedural knowledge, and cognitive strategies. Concerning the acquired knowledge, we should be aware of three kinds of content knowledge consisting of: procedural, declarative, and conditional. Procedural knowledge is knowledge of how to apply the steps in a particular process. An example of such knowledge, applied in CM domain, is knowing how to process to save victims' lives during a big accident. Declarative knowledge is the factual information (theoretical knowledge) that one knows; it can be declared as spoken or written. An example of such knowledge is knowing the different steps to perform in order to save victims' lives during a crisis situation. Conditional knowledge is knowledge about when to use a procedure, skill, or strategy and when not to use it; why a procedure works and under what conditions. For instance, learners-players need to recognize that CM problem requires saving victims' lives as part of its solution.
- **Social and Emotional Outcomes Deduced from Game Mechanics:** This kind of outcome is not related to the learning content or the game as a learning tool, but it is related to the game as an entertainment mean, and more specifically to tools of game-play (Bedwell et al., 2012). In fact, social and emotional outcomes include several social and emotional aspects deduced from relevant play resources of the serious game called "game mechanics" such as human interaction, game fiction or fantasy, immersion, game rules, and challenge.

On the one hand, considering social interactions between players (human interaction supported by technology like instant messaging communication or voice/video chat) (Bedwell et al., 2012) is crucial during evaluating a multi-players CMSG. Social interactions include several factors needed to be evaluated and consisting of: coordination and roles, cooperation/collaboration, communication,

and group decision making. In reality, CM is characterized by a clear definition of roles at the organizational, team, and individual levels; and all the members of a CM team need to coordinate their actions to get the work done (Di Loreto et al., 2012a). Cooperation/collaboration plays also an important role in training games since training of crisis workers is a cooperative/collaborative task. Cooperation may take place inter-sectors (cooperation between different agencies like firefighters and medical units), intra-sector (cooperation between different workers of a given sector) and between crisis workers and citizens (Di Loreto and Divitini, 2013). In addition, communication between the team members is at the core of the training experience, and teaching communication styles is too useful to manage crisis events and to foster team building (Haferkamp et al., 2011). Moreover, the group decision making process is essential to successful group performance in any emergency response plan (Yi et al., 2011). In fact, each player in the group should share his progress and all the relevant information with each other to improve decision making ensuring so a better response to the crisis.

On the other hand, in a CM context, stress management and fear/panic management are essential aspects that should be considered in order to make effective the response to a crisis situation (Nguyen et al., 2014). These aspects are strongly related to some game mechanics like the challenge (referring to the presentation and nature of problems), the game fiction/fantasy (describing the nature of the game world and story), the immersion (determining the players' perceptual and affective relationship with the game fiction), and the game rules (defining the method adopted to solve problems in the game) (Bedwell et al., 2012). For example, (Nguyen et al., 2014) focus on fear emotion since it represents the most predominant emotion in crisis situations and has a great impact on the human decision-making process and behavior. They proposed to integrate emotions, in particular fear, in simulation of evacuation scenario during a crisis. To the best of our knowledge, there is no work aiming to detect and to evaluate emotional states of learners-players (fear, sadness, anger, etc.) during a collaborative scenario of crisis management based on a particular serious game.

The next section aims to discuss the major findings and contributions presented in this article.

5. DISCUSSION

The current state of art of learners' assessment and evaluation in CMSG showed, as mentioned in Introduction section, the absence of a classification for comparative assessment techniques used in CMSG as well as the absence of an evaluation analysis grid for characterizing and evaluating CMSG. To fill these theoretical gaps, we proposed first a new classification of learners' assessment and evaluation techniques for CMSG. This classification aims to classify the most recent existing works in two main approaches: implicit and explicit. For each of these approaches, we presented some techniques currently used in existing CMSG. Our second contribution consists in a theoretical framework for characterizing and evaluating CMSG. In this context, the proposed multidimensional grid is focused on the following two essential desired outcomes: training, as well as social and emotional outcomes. This will not only provide to evaluators or researchers in SG domain relevant aspects to characterize and evaluate CMSG, but it will also be useful for game-designers/developers since it underlines the expected criteria having to be considered in CMSG implementation.

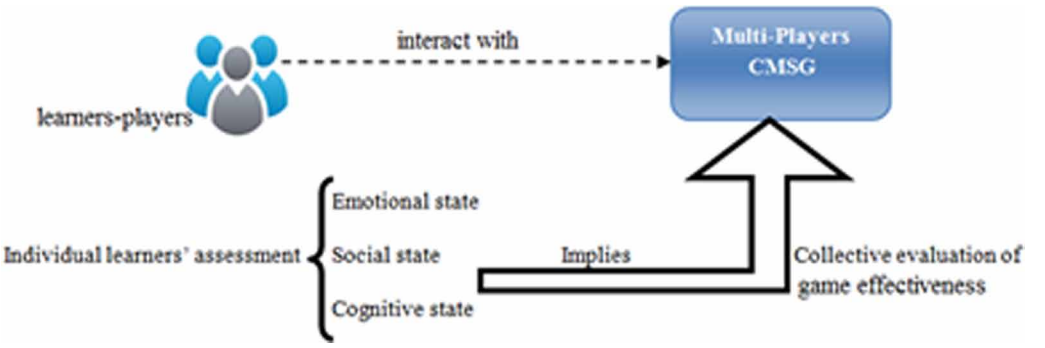
Furthermore, the carried-out literature study showed a lack of works considering both emotional and social aspects in evaluating collaborative CMSG. Indeed, the assessment of CMSG is a complex process having to consider several parameters related to actions and activities performed by the player, the learning context, and the player profile. The complexity of such assessment increases in the case of multi-players SG since we must also take into account social interactions between involved players. In CM context, the considered characteristics of player profile should include cognitive aspects like the initial level of skills, and knowledge acquired during a game session; emotional aspects like fear, and stress; as well as social aspects like communication, and coordination. In order to fill this research gap, we propose to perform both an assessment process on the individual level to assess several learners' aspects, and an evaluation process on the collective level to evaluate the effectiveness of the considered

CMSG. In fact, during their interactions with a collaborative CMSG, an assessment process should take place in order to assess different types of aspects characterizing the learner profile and consisting of emotional, social, and cognitive state. For more details, the assessment of learner emotional state provides relevant information about his sentiments, feelings, emotions, and attitudes while playing the game. In addition, assessing the social state of the learner gives useful information concerning his social relationships with other learners. Moreover, the learner cognitive state needs to be assessed to validate his acquired knowledge and competencies in CM domain. All these assessments allow us to create individual feedbacks based on the profile of each player during the game-based training session. In order to evaluate the effectiveness of a given CMSG, a collective evaluation should be produced by exploiting the results of individual learners' assessments. This collective evaluation allows us to generate a global feedback on the considered game and its effectiveness for crisis management training. Figure 3 gives a global architecture of our vision. In what follows, we will describe the adopted evaluation/assessment techniques to put in practice our vision and in particular to evaluate different learners' states including cognitive, emotional and social states.

An effective SG for crisis management must achieve its learning goals fixed by the game-designer. To attain this objective, a collective evaluation process of players' competencies and cognitive knowledge should take place at the end of a training session. This evaluation can be performed through a debriefing session. In fact, this way remains usually the preferred method for gathering players' feedbacks after a game session especially about their performances. The debriefing session aims to analyze individual and collective performances of players, and to discuss their errors and progress. This session can involve different kinds of participants such as learners-players, domain experts, evaluators, game-designers/developers and researchers in order to provide rich analysis of the acquired knowledge on a qualitative level and thus to generate an evaluation of the game effectiveness for training.

Emotional aspect is the starting point for all of the reactions that we have toward a crisis. Negative emotions such as stress, fear, anxiety, anger, and all unpleasant and unhelpful feelings are the first obstacle to establish a positive response to a crisis. That's why it is essential to consider and to understand the role of emotions in managing a crisis situation (Daoudi et al., 2017). In reality, extracting and analyzing emotions in text-based communication provide insight to better understand how actors communicate and perform during disasters (Beigi et al., 2016). Sentiment Analysis (SA) is "….the task of detecting, extracting and classifying opinions, sentiments, emotions, and attitudes concerning different topics, as expressed in textual input…" (Guthier et al., 2016). SA, also known as opinion mining, has been shown as an effective tool to detect tweets that contribute to situational awareness in CM domain (Beigi et al., 2016; Harvinder and Rajiv, 2015; Torkildson et al., 2014). However, the current approaches for SA only focus on social media platforms, in particular twitter, in order to detect and analyze people' emotions during a crisis situation. In a collaborative CMSG,

Figure 3. Global Architecture of our Vision



we plan to detect and assess learners' emotions and sentiments using SA techniques. Indeed, SA from text messages exchanged between players during a game-based training session is useful for understanding their experiences and analyzing their emotions. SA can be accomplished using various techniques such as Machine Learning (ML), Natural Language Processing (NLP), structured and unstructured Data Mining (DM) (Guthier et al., 2016). In short, sentiment analysis is an important approach that can be used to understand and analyze the attitudes, sentiments and emotions of actors managing a crisis situation.

To the best of our knowledge, there are a limited number of studies aiming to assess social aspects like communication, coordination, cooperation, and group decision-making in multi-players CMSG. However, it is essential to address the role of social interactions between the different members of a CM team in affecting their individual and collective performances (Theo Ovan et al., 2015). In particular, communication as well as coordination and roles are crucial social factors in explaining both team and actor performance during CM training (Haferkamp et al., 2011; Theo Ovan et al., 2015). Recent works of communication and coordination networks in CM have showed that network theory, especially Social Network Analysis (SNA), is a useful method for studying command and control (Theo Ovan et al., 2015). A social network consists of a set of nodes (players-learners) that are connected by ties (communication flow or social relationship) (Ergun and Usluel, 2016). Thanks to SNA method and its measures, learners' patterns of communication and interaction can be measured, analyzed, and visualized. In a collaborative context of CMSG, SNA provides a set of useful indicators to measure and analyze coordination at the team and actor levels (The Ovan et al., 2015). In fact, coordination at the team level can be assessed using network density measures. Density is defined as the proportion of ties existing in the social network to all probable ties (Ergun and Usluel, 2016). This measure is very relevant to display the frequency of information flow and to predict the diffusion rate of shared knowledge between actors. For example, a high value of density in collaborative learning environments shows an important quality of the shared knowledge and so a high level of team coordination (Ergun and Usluel, 2016). On the other hand, coordination at the actor level can be assessed in terms of network centrality indicators like in-degree centrality (the number of in-coming links), out-degree centrality (the number of out-going links), and closeness centrality (the average length of the shortest path between the node and all other nodes in the graph). The centrality of an actor in a social network is relevant to describe his position, to examine how his social interactions evolve over time, and to understand his performance (Theo Ovan et al., 2015). Indeed, the position of an actor in the network is positively related to his learning performance. An actor who has a central position (high level of centrality) in a network is better able to achieve his performance goals (Ergun and Usluel, 2016). To resume applied to collaborative CMSG, SNA represents a powerful and rich method of measuring and assessing social interactions between actors by focusing on specific aspects of the network connection, or the entire network as a whole (Schlauch and Zweig, 2015).

To summarize, in the literature there are a multitude of works developing methods and techniques for assessing CMSG based on different criteria. Several among them are limited to draw judgments about learners' behaviors, but they don't exploit the obtained results to improve the environment or adapt the SG to current characteristics of players. To tackle this problem, we suggest, as a future work, to develop a novel approach for implicit assessment and adaptation in CMSG by taking into account cognitive, emotional and social aspects of players.

6. CONCLUSION

This article presents a survey of the current state of art in learners' assessment and evaluation in CMSG. The study includes major themes identified in the literature by summarizing the main techniques and criteria used in CMSG evaluation. In fact, we proposed firstly a new classification of learners' assessment and evaluation techniques in CMSG where future works can be classified. The principal aim of this classification is to guide the evaluator and/or domain expert in the choice

of the most suitable technique according to his/her needs in order to assess and/or evaluate learners during a training session based on a particular CMSG.

Unlike similar works, we provided also a structure of the most important descriptive features and evaluation criteria, in the form of a grid, that respectively characterize and evaluate a particular CMSG for training. Thus, the proposed grid shows relevant and useful information for deep understanding of the game characteristics and properties. Moreover, the grid provides rich information about success factors to validate the effectiveness of a CMSG for training/learning. From the outcome of our investigation it is possible to conclude that the novel G-CE-CMSG is actually not only a theoretical elaboration of a CMSG evaluation instrument, but also a starting point for further research in this area. The results should be of interest to researchers and game-designers/developers interested in the integration of CMSG in their educational/training programs.

On the basis of the findings presented in this article, work on the remaining issues is continuing and will be presented in future papers. In fact, the next stage of our research will be the development of a novel approach for "stealth" assessment and adaptation of an existing collaborative CMSG supported by "iScen": a software tool for creating interactive scenarios with multimedia content specifically intended for crisis simulation, management, and training. This approach will consider both emotional and social aspects in order to provide relevant information to learners about their emotional and social states and thus to improve their training results.

REFERENCES

Abt, C. (1970). *Serious Games*. New York: The Viking Press.

All, A., Castellar, E. P. N., & Van Looy, J. (2015). Towards a conceptual framework for assessing the effectiveness of digital game-based learning. *Computers & Education*, *88*, 29–37. doi:10.1016/j.compedu.2015.04.012

Alvarez, J. (2007). *Du jeu vidéo au serious game. Approches culturelle, pragmatique et formelle* [PhD thesis]. Université Toulouse II - Toulouse le Mirail et Université Toulouse III - Paul Sabatier.

Anita, C., Hester, S., Dolf, B., Maaike, R., & José, K. (2015). Does playing the serious game B-SaFe! make citizens more aware of manmade and natural risks in their environment? *Journal of Risk Research*, *18*(10), 1280–1292. doi:10.1080/13669877.2014.919513

Bedwell, W., Davin, P., Kyle, H., Lazzara, E., & Salas, E. (2012). Toward a Taxonomy Linking Game Attributes to Learning: An Empirical Study. *Simulation & Gaming*, *43*(6), 729–760. doi:10.1177/1046878112439444

Beigi, G., Hu, X., Maciejewski, R., & Liu, H. (2016). An overview of sentiment analysis in social media and its applications in disaster relief. In Sentiment Analysis and Ontology Engineering (pp. 313-340). Springer International Publishing. doi:10.1007/978-3-319-30319-2_13

Bellotti, F., Kapralos, B., Lee, K., Moreno-Ger, P., & Berta, R. (2013). Assessment in and of serious games: An overview. *Advances in Human-Computer Interaction*, *2013*, 1–11. doi:10.1155/2013/136864

Boughzela, I. (2014). *Characterizing the Serious Game and Assessing Learning Goals.* Telecom École de Management, Institut Mines-Telecom.

Callies, S., Gravel, M., Beaudry, E., & Basque, J. (2017). Logs Analysis of Adapted Pedagogical Scenarios Generated by a Simulation Serious Game Architecture. *International Journal of Game-Based Learning*, *7*(2), 19. doi:10.4018/IJGBL.2017040101

Carole, A., Franck, T., Etienne, D., Odile, P., & Mira, T. (2016). SPRITE-Participatory Simulation for Raising Awareness About Coastal Flood Risk on the Oleron Island. In *International Conference on Information Systems for Crisis Response and Management in Mediterranean Countries* (pp. 33-46). Springer International Publishing.

Daoudi, I., Tranvouez, E., Chebil, R., Espinasse, B., & Chaari Lejouad, W. (2017). Learners' Assessment and Evaluation in Serious Games: Approaches and Techniques Review. In *Information Systems for Crisis Response and Management in Mediterranean Countries* (pp. 147–153). Springer International Publishing. doi:10.1007/978-3-319-67633-3_12

Di Loreto, I., & Divitini, M. (2013). Games for Learning Cooperation at Work: the Case of Crisis Preparedness. In *ECTEL-meets-ECSCW: Workshop on Collaborative Technologies for Working and Learning* (pp. 20-24).

Di Loreto, I., Mora, S., & Divitini, M. (2012a). Collaborative Serious Games for Crisis Management: An Overview. In *Proceedings of the IEEE International Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises* (pp. 352-357). doi:10.1109/WETICE.2012.25

Di Loreto, I., Mora, S., & Divitini, M. (2012b). Don't Panic: Enhancing Soft Skills for Civil Protection Workers. In *Serious Games Development and Applications. SGDA*. Springer. doi:10.1007/978-3-642-33687-4_1

Emmanouil, D., & Nikolaos, D. (2015). Big data analytics in prevention, preparedness, response and recovery in crisis and disaster management. In *18th International Conference on Circuits, Systems, Communications and Computers, Recent Advances in Computer Engineering Series* (pp. 476-482).

Ergun, E., & Usluel, Y. K. (2016). An Analysis of Density and Degree-Centrality According to the Social Networking Structure Formed in an Online Learning Environment. *Journal of Educational Technology & Society*, *19*(4), 34–467.

Guthier, B., Dörner, R., & Martinez, H. P. (2016). Affective Computing in Games. In Entertainment Computing and Serious Games, LNCS (Vol. 9970, pp. 402-441). Cham: Springer.

Haferkamp, N., Kraemer, N. C., Linehan, C., & Schembri, M. (2011). Training disaster communication by means of serious games in virtual environments. *Entertainment Computing*, *2*(2), 81–88. doi:10.1016/j.entcom.2010.12.009

Harvinder, J. K., & Rajiv, K. (2015). Sentiment analysis from social media in crisis situations. In *IEEE International Conference on Computing, Communication and Automation*.

Mendez, G., Avramides, K., de Freitas, S., & Memarzia, K. (2009). Societal impact of a Serious Game on raising public awareness: the case of FloodSim. In *Proceedings of the ACM SIGGRAPH Symposium on Video Games* (pp. 15-22).

Michael, D., & Chen, S. (2005). *Serious Games: Games that Educate, Train and Inform*. USA: Thomson Course Technology.

Mora, S., & Divitini, M. (2014). Supporting Debriefing with Sensor Data: A Reflective Approach to Training. *In Information Systems for Crisis Response and Management in Mediterranean Countries. Lecture Notes in Business Information Processing*, *196*, 71–84. doi:10.1007/978-3-319-11818-5_7

Nguyen, V. T., Longin, D., Ho, T. V., & Gaudou, B. (2014). Integration of Emotion in Evacuation Simulation. In *International Conference on Information Systems for Crisis Response and Management in Mediterranean Countries* (pp. 192-205). Cham: Springer.

Oulhaci, A., Tranvouez, E., Fournier, S., & Espinasse, B. (2015). Improving Players' Assessment in Crisis Management Serious Games: The SIMFOR Project. In *International Conference on Information Systems for Crisis Response and Management in Mediterranean Countries* (pp. 85-99). Springer International Publishing. doi:10.1007/978-3-319-24399-3_8

Petri, G., & von Wangenheim, C. G. (2016). How to Evaluate Educational Games: A Systematic Literature Review. *Journal of Universal Computer Science*, *22*(7), 992–1021.

Sagun, A., Bouchlaghem, D., & Anumba, C. J. (2009). A scenario-based study on information flow and collaboration patterns in disaster management. *Disasters*, *33*(2), 214–238. doi:10.1111/j.1467-7717.2008.01071.x PMID:18699856

Schlauch, W. E., & Zweig, K. A. (2015). Social Network Analysis and Gaming: Survey of the Current State of Art. In Joint International Conference on Serious Games (pp. 158-169). Cham: Springer.

Silva, V., Dargains, A., Felício, S., & Carvalho, P. et al. (2014). Stop disasters: serious games with elementary school students in Rio de Janeiro. In *8th International Technology*, *Education and Development Conference* (pp. 1648-1659).

Sooraj, K., Marcia, L., Bijlani, K., Jayakrishnan, R., & Bhavani, R. (2016). Collaborative Game Based Learning of Post-Disaster Management: Serious Game on Incident Management Frameworks for Post Disaster Management. In *IEEE 8th International Conference on Technology for Education.*

Tena-Chollet, F., Frealle, N., Bony-Dandrieux, A., & Tixier, J. (2016). Design of a Semi-Virtual Training Environment (Serious Game) for Decision-Makers Facing up a Major Crisis. *Chemical Engineering Transactions*, *48*, 853–858.

Torkildson, M. K., Starbird, K., & Aragon, C. (2014). Analysis and Visualization of Sentiment and Emotion on Crisis Tweets. In *Cooperative Design, Visualization, and Engineering,* LNCS (Vol. 8683). Springer. doi:10.1007/978-3-319-10831-5_9

van Ruijven, T., Mayer, I., & de Bruijne, M. (2015). Multidisciplinary coordination of on-scene command teams in virtual emergency exercises. *International Journal of Critical Infrastructure Protection*, *9*, 13–23.

Walker, W. E., Giddings, J., & Armstrong, S. (2011). Training and learning for crisis management using a virtual simulation/gaming environment. *Cognition Technology and Work*, *13*(3), 163–173. doi:10.1007/s10111-011-0176-5

Yi, P., Yong, Z., Yu, T., & Shiming, L. (2011). An incident information management framework based on data integration, data mining, and multi-criteria decision making. *Decision Support Systems*, *51*(2), 316–327. doi:10.1016/j.dss.2010.11.025

Zagorecki, A. T., Johnson, D. E. A., & Ristvej, J. (2013). Data mining and machine learning in the context of disaster and crisis management. *International Journal of Emergency Management*, *9*(4), 351–365. doi:10.1504/IJEM.2013.059879

Zyda, M. (2005). *From visual simulation to virtual reality to games*. IEEE Computer.

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