Collaborative serious games for crisis management: an overview

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Abstract— **Training in the field of crisis management is complex and costly, requiring a combination of approaches and techniques to acquire not only technical skills, but also to develop the capability to cooperate and coordinate individual activities towards a collective effort (soft skills). In this paper we focus on serious games for increasing participants' skills in a playful manner. In the paper we identify general issues characterizing crises management and we analyze the state of the art of serious games for crisis management in order to understand strengths and weaknesses of these environments.**

Keywords: Crisis management; serious games; soft skills.

I. INTRODUCTION

Preparedness is core to crisis management [1]. Within this phase we focus on training and learning, and in particular on learning from experience [2]. In crisis management learning from experience is promoted through structured debriefing sessions for collaborative re-assessment of the response given to a specific emergency in terms of e.g. application of existing protocols and team coordination. These sessions help workers and their organizations to learn how to perform better in the future. However, learning from experience is challenging because crisis work is scattered in time and space. Consequently experiences that individuals and units can gain are fragmented, sporadic, and partial. It is therefore difficult to promote reflective learning only relying on real experiences. As a complement to real experiences, exercises that are simulating different crisis scenarios are regularly organized. These exercises can be seen as field tests that allow acquiring experience on specific events in a controlled and safe environment. Simulations generally involve different forces to manage an event, for example an earthquake. In this way, the simulation serves to test not only the responsiveness of a specific body, e.g. firefighters, but also the capability of different forces to coordinate their activities. Simulations are however very costly, requiring a large deployment of personnel and equipment. For this reason, computer based simulations have been proposed to facilitate training (e.g. [3],[4]).

In this paper we discuss the potential of serious games in this domain. A serious game is a way of providing participants with a fun experience from which they can learn more about themselves and their interaction with their world. Starting from their introduction computer based serious games have been successfully adopted in different fields such as the army – see e.g. the U.S. Army's release of the video game *America's Army* in 2002 [5] – and the health field, e.g. with the game *L'affaire Birmain* to teach children

how to manage their diabetes [6] and post stroke rehabilitation games [7]. Games support players in exploring a set of possibilities and playing with different solutions, fulfilling goals in a variety of unique, sometimes, unanticipated ways. The fun factor is intended to act as a motivation to play repeatedly and therefore gain different perspectives on the space of possibilities. In particular, while it might be difficult to learn hard skills for emergency management with a serious game, there is a good potential to develop soft skills (e.g., communication styles during a crisis, team management and coordination, time management, stress management)[25]. We are in no way suggesting the use of serious games as an alternative to simulated events and computer based simulations, but rather as a complement in training. Being less costly and targeted to a larger audience, games might open new forms of training for emergency workers, volunteers and the population at large.

In the rest of this paper we (i) characterize crisis management, and (ii) use these elements to analyze existing serious games for crisis management in order to understand strengths and weaknesses of these environments.

II. CHARACTERIZING CRISIS MANAGEMENT

Crisis management is complex and we do not aim at its complete characterization, but rather outline general issues to consider when designing serious games. Let's use a simplified example to help us in this task. (The working example is fictional, but it is inspired by interviews we conducted with workers of the Italian Civil Protection.) During a weekday, a truck transporting toxic material has an accident. If it gets in contact with air, the material could cause a major air contamination. The problem requires the coordinated intervention of multiple units: firefighters trying to avoid contamination; medical units taking cares of the injured; police trying to avoid traffic problems; Civil Protection activating evacuation plans and preparing sheltering for the population. As it is often the case, we are dealing with a wicked problem, i.e. a problem that does not have a univocal solution, but different solutions with associated costs and risks. In this scenario we can identify:

Predictable and Unpredictable elements: A complex interleaving of predictable and unpredictable events characterizes most crises. In our example, accidents involving vehicles transporting hazardous material are a well-known problem for which protocols of action are defined. However, nobody can predict when this will happen and the precise context, e.g. type of material, weather

conditions, or population in the area. The involved units must manage the emergency as it unfolds.

Problem dissection: During a crisis, the main problem is broken down into manageable sub-problems, e.g. taking care of the injured, putting population in safe conditions, and so on. Generally, specific emergency units are allocated to each sub-problem.

Making plans: Once the main problem is dissected, action has to be planned. Each unit might define plans for sub-problem they have to handle, but with the need to coordinate the effort. Plans have to conform to approved protocols of action. They might act as maps or scripts depending on the specific situation and the role of the people involved, for example volunteers with low training have generally no authority to change a plan.

Local optimum vs. global optimum: Action leading to an optimal result locally is not always leading to the intended global result. For example, divert the traffic in one direction might reduce congestion in one area, but create problems to emergency vehicles parked in another road.

Communication and cooperation: Members in a crisis management team need to communicate to coordinate their action, e.g. keeping updated and negotiating changes in the plan, but also to cooperate to get the work done.

Roles: Crisis management is characterized by a clear definition of roles at the organizational, team, and individual level. Members of the emergency team can aggravate the situation if they do not accept leadership or refuse to act within their, possibly limited, action space.

Limited time for decision-making: In most crises, events can quickly deteriorate. In our example, the truck can start spilling out hazardous material and contaminate the air if the emergency team is not able to act quickly.

Links to the territory: Crises do not happen in a vacuum, but are deeply grounded in specific social and physical contexts that influence their management, e.g. an event like the one in our working example happening in a highly populated area with schools nearby poses different requirements than if the accident happens in an isolated area.

Asymmetric information: Not everybody has access to the same information. Coordinators might have a better overall perspective, while workers deployed in the field might have more detailed and updated information regarding a specific area. No one can be sure to work with information that is complete, fully reliable, and accurate.

Quick convergence towards an objective: Though the time span varies with the specific situation, crisis management has the aim to quickly converge towards the "normalization" of the situation.

Coaching: Crises involve people with different levels of knowledge and experience. Actions that are almost routine for some of the workers might be extremely challenging for newcomers, both technically and in terms of emotional response. Though there is often limited time for discussion, and everybody has to act within their role and time constraints, there are continuous micro-sessions for informal coaching where workers support each other, providing suggestions and warnings.

Debriefing: After each event a debriefing session takes place to understand the critical aspects linked to the intervention. Debriefing sessions might significantly vary in terms of level of detail and people involved. For example, debriefing sessions might be conducted separately from each unit or together, if the focus is on coordination. Workers at all levels might be involved to use the session as an occasion of reflective learning at the individual and team level, while in other cases it might involve only top management to reflect of suitability of the defined protocols.

As we can see crisis management is a task that can rise in complexity very quickly. Emergencies are made up of both foreseeable and unexpected elements. Crisis management works exactly anticipating the former in order to minimize the latter [9]. One of the ways to anticipate foreseeable events is building predictive models, or scenarios, of what is likely to happen in the future and use these models for training. Managing unexpected elements requires instead to learn not only how to behave during the crisis, but also the importance of passing the right information, in the right amount, at the right time, from the right place, to the right person (the so-called soft skills)[10].

III. CRISIS MANAGEMENT TRAINING: FROM SIMULATIONS TO SERIOUS GAMES

Crisis management workers cannot train for their jobs with real-life events because every situation is different and they cannot create a catastrophe just for the purpose of training. For this reason trainings in the crisis management field have been supported firstly through manuals and then through real life simulations, trying to reproduce as much as possible real life situations to teach best practices. In addition, particular kinds of interventions were developed to train non-technical skills, for example courses such as Crew Resource Management (CRM), Human Factors, or Team Resource Management are increasingly being introduced [12].

The importance to support both aspects – specific procedures and soft skills- is underlined by the fact that: "The key to effective crisis management lies not so much with the writing of detailed manuals (that have a low likelihood of being used) and practicing location evacuations as with structured and continuous learning processes designed to equip key managers with the capabilities, flexibility and confidence to deal with sudden and unexpected events." [13] In addition, many teamwork articles stress the importance of establishing teamwork skills - such as communication and coordination - in order to survive in uncertain and dynamic environments [14].

One of the ways to address this complex scenario could be the usage of serious games. The main difference between simulations and serious games is that while simulations focus on best practices, defining paths to follow to do the "right" work, games are more focused on the "rules of play", that in our case could be the way to interact each other for a successful coordination in crisis management. A serious game can help participants to see things differently (and act differently) from the way they are used to act. As we said

crises are characterized by the absence of obvious solutions, the scarcity of reliable information when it is needed, and the lack of adequate time to reflect on and debate alternative courses of action. While simulation can help the crisis management team to find the optimal response to the crisis, serious games can help them for example in the art of optimizing the limited time that they have to develop creative responses to the crisis. The flexible rule structure can allow the learners to explore the game space, test hypothesis, and fulfill goals in a variety of unique, sometimes unanticipated, ways. The great degree of flexibility and range of plausible paths to success can help learners to develop a flexible knowledge base that can be applied to a variety of real world situations [15].

Now, while presented this way serious games could seem the panacea for all problems, there are two serious limitations to take into account. The first one is that participants will not learn everything they need to know from the serious game. "Learners will not learn to use a scalpel by handling a virtual one using a joystick, nor learn perfect bedside manners by ''talking'' with NPCs. Yet, just as pilots learn some elements of flying in flight simulators, medical students can learn some aspects of being a practicing doctor from serious games."[15] That's why we believe the use of both, real life simulations and serious games can add value to crisis management training. The other limitation we can list it's more linked to the "state of the art" of serious games for crisis management. As far as we know there are no "best practices" or at least a list of elements which are needed to create a successful "soft skills" training environment.

IV. STATE OF THE ART OF SERIOUS GAMES FOR CRISIS MANAGEMENT

In this section we analyze 10 games and simulations we think can add "food for thought". These papers were selected from a larger range of papers addressing computer based crisis management training. The largest part of the analyzed papers was about non-game based simulation, and was then discarded. Same happened to single player games. In the resulting 10 games list while we take into applications cross mixing both, game and simulation. The analyzed papers were then discussed according to the elements listed in Section II, in order to understand if and in which way crisis management aspects were taken into account. Table I lists the analyzed works providing a short summary of their scenarios.

TABLE I.   LIST OF ANALYZED GAMES

	Type	Scenario Subhead
Interactive Simulation in Crisis Management[16]	Simulation	System based on (human and virtual) agents which enables interactive simulation for crisis management targeted at emergency workers and coordinators.
Gaming and multimedia applications for environmental	Game	Interactive game simulation to support the training staff during the preparation, the execution and the evaluation of Crisis Unit

	Type	Scenario Subhead
crisis management training [11]		exercises.
Web-based micro-world simulation for emergency management training [17]	Simulation	System used for investigation and training experimentation of team decision making and situation awareness targeted at fire fighters.
Incident Commander[18]	Game	Teaches incident management for multiple scenarios, including terrorist attacks and natural disasters targeted at Public Works, EMT, Police, and Fire units.
Hazmat: Hotzone [19]	Game	Trains firefighters to better respond to hazmat calls.
EMERGENCY 2012[20]	Game	Revolves around micromanaging emergency services on a variety of accident and/or accident scenes. Targeted at rescuer workers.
RESCUE SIM[21]	Game	Multidisciplinary training software that prepares public safety and security professionals for real-life incidents in a virtual environment.
Crisis Planning via Scenario Development Gaming[22]	Game	A competitive game to have opposing defense and offense teams develop and improve their respective plans for defense and offense.
Situated learning with co-operative agent simulations in team training [23]	Simulation	Uses intelligent agents, team-based instructional design theories and models of cognition to improve learning and performance outcomes.
The DREAD ED Game [24]	Game	Places its users in a crisis management team that is dealing with an evolving emergency (e.g. a huge fire close to a chemical park).

The rest of this section summarizes the results of the analysis.

A mix between Predictable and Unpredictable elements: As we have seen from the analysis, in real life decisions are taken in a dynamic context with predictable and unpredictable events taking place. While mostly of the analyzed works explicitly introduce a mix of predictable and unpredictable events, they use different approaches. [16] for example uses an agent based software platform for dynamic simulation of disasters and an event generator which can generate different crises situations. Some actions may have an impact on the event generator, so there is an interaction between agents and event generator. Finally users can play the role of agents so there is a mix of human and artificial agents. This work is an interesting example about how dynamic computer based simulations could improve real life simulation and be used to customize the learning experience. On the other hand [11], [18] and [21] use scenarios to customize the learning experience and add variety in the game. This approach is useful to adapt the learning experience -for example with the addition of, buildings,

structures, crisis events, and emergency agencies to more accurately portray local community situation – and offers a great freedom in practicing different incident trends. However, used as the only adaptation element it can lower the dynamism of the game experience. Keeping this approach will create the same problem as real life simulations where scenarios are more or less pre-defined. If the disaster management staff decides to take a decision that was not foreseen by the training staff in advance, such a decision cannot be developed during the exercise because it does not fit into the scenario [11].

Problem dissection; Making plans; Local optimum vs. global optimum: While these aspects could be inferred in some way from the games rules used in the listed works they are strongly dependent from the actual game session. For example how the team decides to split-up an intervention strongly depends from the current game state. For this reason we will note enter into detail in the topic here. However, we want to underline a particular approach to the matter. [22] describes a particular competitive game for crisis management training. The fundamental kernel of the game defines two teams: Defensive Planning Team and Offensive Threat Team. The defense team seeks to develop a plan to defend a particular facility. The offense team designs a threat in the form of a scenario that says how they are going to launch an attack and what is going to occur over time with the resources (both people and equipment) they have been provided to conduct their attack. For crisis management the offense team is designing a specific natural disaster that impacts an area in their locality. The authors' point of view is that the way we understand and try to analyze a real crisis situation is by investigating and relating series of events (the Hegelian Inquiry Process as characterized by Churchman [26]). In this process two opposing world views are created that are constructed to be the most extreme in being opposite to one another. These two views about the future are than compared with the expectation that a collaborative group can reach a consensus on a synergistic combination that represents an improvement over either extreme view.

Communication and cooperation: All the analyzed works put communication between the team members at the core of the learning experience. However we can distinguish two kinds of approaches. From one hand the system generates a task environment in which a group of people co-operate to deal with a crisis. In works such as [17] for example the task of the staff is to have an overview of the situation and to co-ordinate and schedule the fire-fighting units so that they can extinguish the fire and save the houses. Other works use a more hierarchical approach. In [19] one player assumes the role of the incident commander and establishes a decontamination zone. The others players communicate over radios and respond to the situation accordingly.

Roles: Most of the analyzed works take into consideration different roles inside the game. [24] for example, places its users in a crisis management team that is dealing with an evolving emergency (e.g. a huge fire close to a chemical park). Each member is assigned a specific role that has unique abilities. These roles (e.g. leader of the team) are based on the roles of members of crisis units in reality.

An interesting approach used by few works is cross training – i.e., shifting to different roles - to provide learners with a more elaborate perspective of the situation or problem. As Charsky notes: " switching role could be used in a firefighter training serious game where the trainee can switch from a firefighter battling the three-alarm inferno, to the firefighter operating the ladder truck, to the chief managing the squad."[18 pp.186] Using role switching would require the learner to learn a variety of skills and provide a broader, more detailed understanding of the processes and roles of a team. [17] and [23] are an interesting example about how to use role switching to teach different skills. In [17] the players who run the system are part of a fire-fighting organization. While the roles are predefined they can take on the roles as staff members or fire-fighting unit chiefs. [23] on the other hand, proposes cross training during the same simulation together with special reifications for reflection. The simulation-based environments afford opportunities to exercise these competencies through the inclusion of intelligent agents that both make errors and have the capability of exhibiting the competencies.

Limited time for decision-making: For crisis management, it's very important to create time compelling games. At the game design level designers can think of two ways of implement this aspects (i) generate a quick convergence (to push the players to quickly win or lose), or (ii) give a time limit to the game session (e.g., the players will have one hour to complete the goals otherwise they will lose). Almost all the analyzed works address this aspect inserting unexpected events which accelerated the convergence of the game or the simulation (thus implementing (i)) avoiding giving an explicit time limit.

Links to the territory: Most of the analyzed games miss a strict link with a real territory. An interesting exception are [11], in a light way, and [21] in a more in depth way. In [11] during the training session the Crisis Unit stays in a room resembling as much as possible control rooms used in real settings.. Reports concerning the development of the simulated disaster are given to the trained officials via the usual lines of communication. In [21] the game is played in a dedicated training centre that is divided into six different training areas, where incident commanders from all levels can train virtually, exactly as if it were a real life situation. The training centre is built according to the incident command structure used in the UK. Incidents are approached from four sectors, front, back, left and right. The training rooms (pods) correspond with these sectors and the different screens show what is going on in a specific sector of the incident, according to where the different levels of command – bronze, silver, gold – would be normally stationed.

None of the games that we analyzed promote exploration and acquisition of knowledge about a specific territory where an emergency can unfold, neglecting the vital role of *place* in crisis management [8]. This lack of acknowledgement is borrowed from real life simulations as in real life the emergency management staff most of the time does not train

in their own area with their specific characteristics, which would be much more stimulating and motivating [11].

Asymmetric information: Interesting enough most of the analyzed works doesn't take into account this aspect. The ones which do it – [18], [23] and [24] – use an approach taken from real life: they link the kind and amount of information to the player's role. However a real life emergency is more complex. For example an emergency worker could have access to a particular kind of information because he is in a particular zone, and this information could not be accessible to the coordinators. In the analyzed works situation is simplified and this aspect is not taken into account.

Quick convergence towards an objective: This aspect is strictly linked to *Limited time for decision making*, and *Communication and cooperation*. In fact, not only time compelling games are useful to activate reactions in stressful situation; they can also be used to teach communication styles in order to quickly converge towards an objective [24].

Coaching and debriefing: While serious game potentially could provide a powerful learning experience, some type of coaching and or debriefing activity are needed [15]. Most of the analyzed works - such as [23] - use a classical approach to the coaching and debriefing problem. Through the observation of past performance, with and without peer commentary, and practice with the situated representations, team members will be encouraged to demonstrate these competencies and reduce error. [19] and [24] address in a more in depth way the problem of coaching and debriefing. In [24] a tutor who does not have a physical representation within the game supervises the game play and conducts a face-to-face discussion after the game. In [19] the program begins with an instructor creating the hazardous scenario. She is to determine such factors as the location of the hazard, its effects, the weather conditions, and the placement and symptoms of the victims involved. The instructor has the ability to pause the game or trigger unexpected actions and secondary events at any time. She may even incapacitate a first responder who has taken an unsafe action. When the scenario has been completed, the instructor can then lead a discussion using specific examples of what actions were and were not effective. The scenario can then be repeated to test for lessons learned, or a new scenario can be loaded to train for different situations.

V. DISCUSSION

The analyzed games offer an interesting complement to traditional training. Though for none of them we have been able to find long-term evaluation of their impact, initial results of usage show they are promising tools addressing some of the limitations of traditional training. The available games greatly vary in terms of required organizational commitment, audience, and scenarios. They therefore provide a good overview of the spectrum of possible uses of games for training in crisis management, ranging from tools that can easily be adopted by a team to systems that require the involvement of top management, for example because of their cost as in [19].

The analyzed examples also provide some interesting lessons learned about how games can be designed to address some of the limitations of current training activities. For example, the usage of software agents, like in [16], can support the dynamic generation of scenarios overcoming real life simulations where scenarios are more or less pre-defined.

The tools that we analyzed have different foci and therefore they generally address only a sub-set of the issues identified in Section II. There is however some issues that seems to be generally neglected.

In particular: (i) there is limited link with an actual territory (i.e., the game takes place in an abstracted environment); (ii) there is virtually no possibility to play with roles; (iii) the importance of the debriefing phase is underestimated, (iv) there is no support for coaching during the playing sessions. The last two aspects are particularly critical because they are directly connected with the capability of a tool to promote learning.

As we have seen crisis management is a task that can rise in complexity very quickly and it's very difficult to cope with this complexity when designing a serious game. Crisis management involves different kind of competencies, from very specific procedures to soft skills. It involves also different kinds of workers, from very trained ones to less trained volunteers. Trying to create a unique game to address all the elements and all the targets could not only be useless but also counter-productive. For this reason we suggest to create an ecology of serious games, able to address different targets and skills using different games.

In particular we suggest that it could be possible to identify recurring patterns in crisis training which can be reintroduced in the serious game design phase in order to address different skills. For example a game can integrate patterns for team management, information management, and territory management if addressing coordinators; patterns linked to communication skills if addressing volunteers; and so on.

The other advantage of this approach is linked to the fact that with respect to real life or very specific computer based simulations, games might be less costly. Keeping costs low can help in targeting a larger audience, opening this form of training to e.g. more volunteers and the population at large. A serious game approach can then help to involve normal citizens during the crisis management, as these environments could also be used to sensitize population about the most relevant problems linked to the territory.

VI. CONCLUSIONS AND FUTURE WORKS

As we have seen from the previous analysis, crisis management training through serious games has the potential to develop different skills: the ability to anticipate; an enhanced capability for teamwork; learning to cope with short response times; a better understanding of the value of/need for stress management; sharpened business judgment skills; enhanced lateral thinking and creative skills; greater sensitivity to weak signals of abnormality; and better acceptance of change. All these aspects are skills needed for crisis management [13].

In addition, the analysis conducted in this paper underlined two elements: (i) in the design phase of a game for crisis management training the elements listed in Section II have to be taken into account (and if they are not used this decision should be motivated); (ii) trying to create one serious game to address a so complex matter not only could be useless but also counter-productive. For this reason we suggested to create an ecology of serious games, based on patterns derived from crisis training, able to address different targets and skills using different games.

As it's evident, this kind of approach opens several research questions. One of the main theoretical research questions is linked to how we can identify and validate the patterns we want to use for designing serious game.

A second question is linked to the modalities of interaction. In fact allow free interactions not only between the participants but also with the environment is very important to support reflective learning and soft skills development. How we can support these multiple spaces of interactions is then an interesting complex research space.

For the above mentioned reasons our current researches are progressing at both levels (i) the analysis of crisis training to find patterns able to support in particular soft skills and (ii) the design and development of a serious game to be played in a distributed way, allowing at the same time centralized management from the coordinators' part and interaction with the territory from the active workers part.

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