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Simulations in virtual reality: assessment of firefighters' decision-making competence

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Abstract: This study focuses on the use of virtual reality simulations for the training of portuguese firefighters in emergency operations management and the assessment of decision-making competence. The research was carried out through the action-research method. In the first cycle a pilot training course was carried out in a group of eight trainers from the Portuguese National Fire Service School, in which data were collected on the performance of trainees and in the evaluation of training. In the last step, corrections and improvements to the training course were identified. In the second cycle of action-research the steps were repeated with the formal implementation of the training course for eight fire officers of several fire brigades in the country. Every trainee played the role of incident commander in two different training scenarios and their performance was assessed at both times using a common evaluation tool. The evaluation of the impact of the changes introduced in the second cycle was carried out through a comparative analysis of the learning assessments, the evaluations of the trainees of the two groups and the evaluation of the team of trainers. The results of the trainees' performance and the training evaluation allow to conclude that the training course promoted the development of decision-making competence in the management of emergency operations using virtual reality simulations.

Key words: Firefighters, training, competence, decision making, virtual reality simulation.

1. Introduction

Fire brigades are required to respond daily to different incidents within the scope of their mission activities. Decision-making required in emergencies, where the occurrence develops dynamically in a short period, available information is limited and decisions are made under high pressure, posing major challenges for decision-makers (Klein, 2008). Correct and timely decision-making competence define the effectiveness and efficiency of fire brigade interventions by limiting the consequences of events in terms of human, property and environmental losses and preventing accidents with the firefighters themselves. Effective decision-making is essential for the success of the mission and the safety of firefighters (Hall, 2010).

The practical component of emergency operations management training is usually based on conducting simulation exercises in different operational contexts. Until very recently, trainees were faced with classroom-designed scenarios using PowerPoint presentations and one-shot image sequences, which throughout the exercise exhibited changes corresponding to the evolution of the situation, although limited to a very small number of predefined options.

The introduction of a virtual reality simulator in the training allowed the conception of scenarios of high fidelity compared to firefighters' real working conditions, recreating situations of great complexity or risk. These virtual environments make it possible to train decision-making, allowing mistakes to be made and learners to learn from those mistakes,

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safely and without consequences for themselves or for others.
The assessment of professional competencies must include the assessment of knowledge, skills and attitudes. To assess whether trainees have acquired the required level of skills, new forms of assessment should be used, such as simulations or assessments in typical work situations. For this purpose, virtual reality technologies have great potential by allowing the development of virtual environments that reproduce real working conditions.

According to Morgado (2009) the advantages of virtual simulation are evidenced in many research works that have approached the simulations, either in terms of its effects and content, in terms of its development and pedagogical practices, or even intersecting the different approaches. However, it is also possible to find many studies that focus on virtual simulation in a purely technological perspective, pointing only requirements and potentialities, leading to the results of the introduction of this tool in the teaching-learning process not always conclusive, since the researchers ignored other fundamental aspects such as the context and the pedagogical methods that define the circumstances in which such technology was used.

This study, conducted as part of a Ph.D. research, aims to explore the application of virtual reality simulations (VRS) in training context, through the design of a training course that aims to develop decision-making competence for firefighters in the management of emergency operations.

2. Virtual Reality Simulation

Simulations can take many forms and be considered as a set of techniques and technologies, from verbal role play to virtual worlds (Keskitalo, 2015). Simulations provides a learning opportunity that is both immersive and experiential (Aggarwal, *et al*., 2010).

Virtual reality encompasses a wide range of technology, from computer-visualized simulations to virtual reality glasses that can be equipped with sophisticated motion detection systems (Blade & Padgett, 2002). Although the technology may be varied, the common feature is that it provides a human-computer interface that simulates an alternate three-dimensional environment and presents a multisensory stimulation to the user (visual, auditory, haptic, olfactory or otherwise), enabling the user to interact with the synthetic environment in real-time (Stanney e Cohn, 2009).

The use of simulators that use virtual reality systems to train professionals in different sectors of activity has been mentioned for several decades, namely in the aeronautics (Blow, 2012), medicine (Ravert, 2002; Gomoll, Pappas, Forsythe, & Warner, 2008), and nursing (Hovancsek, 2007; Decker, Sportsman, Puetz & Billings, 2008) sectors, in the military área (Christ, 2006), emergency services (Andreatta, *et al*., 2010; Farra & Miller, 2013) and fire service (Hall, 2010; Bliss, Tidwell & Guest, 1997; Bayouth, 2011; Gillespie, 2013).

Virtual reality simulation is a flexible tool that can be used on its own or in conjunction with more traditional training methods. However, some learning outcomes are easier to achieve in a simulated environment. Scenarios can be specifically designed to the desired level of complexity and can be easily reproduced. Simulations can be interrupted, controlled and repeated and allow firefighters to prepare for situations that are not always possible to simulate under real conditions (Launder, Lamb, Olde & Link, 2015). By eliminating the displacement of real resources and equipment and providing access to training for a larger number of trainees, it also becomes a lower cost solution.

In some European countries (France, UK, Germany, Netherlands) simulations in virtual reality technology are used for the training and assessment of fire officers who perform incident command functions, at the tactical and strategic level of operations management. The assessment of the specific learning results for each exercise is carried out according to national professional qualification standards (Launder, *et al*., 2015).

Virtual reality simulation has a set of requirements which include:

a) Physical and psychological fidelity: Physical fidelity refers to how simulation is successful in reproducing the physical aspects of the environment, notably in terms of visual appearance and sound. In turn, psychological fidelity refers to the degree to which simulation captures the functional and cognitive aspects of the performance domain (Hayes & Omodei, 2011; Entin, Elliott & Schiflett, 2001).

b) Interaction: User interaction with the virtual environment is performed through an interface that acts as an extension from the physical to the virtual environment. The possibility of the user interacting with the virtual environment, by manipulating and moving objects, and visualizing the simulator's response to their actions, reinforces the user's presence in this environment (Mantovani & Castelnuovo, 2003).

c) Immersion: Immersion is the subjective impression that you are participating in a comprehensive and realistic experience regardless of the interface used to achieve it (Lessiter, Freeman, Keogh, & Davidoff, 2001). A virtual environment that promotes a more intense sensory immersion experience will generate a greater sense of user presence (Dede, 2009).

d) Realism: The perceived value of training depends on the extent to which it accurately reproduces real-life situations and for which it requires participants to engage in the behaviours that will be required in those situations (Launder, *et al.*, 2015). The realism of the simulated situation influences the student's perception of the usefulness of the learning experience and the subsequent transfer of learning to the real work context (Lathan, *et al.*, 2002).

3. Pedagogical model

Several studies address the exploitation of VRS in the context of firefighter training (Hall, 2010; Bliss, Tidwell & Guest, 1997; Bayouth, 2011; Gillespie, 2013; Cohen-Hatton & Honey, 2015). However, it was not possible to recognize in any of these research works the adoption of a specific pedagogical model for teaching-learning processes involving this technology.

Given the absence of a model that would allow the pedagogical activities to be framed, according to the role of the actors in the training process, trainers and trainees, we decided to adopt the pedagogical model developed by Keskitalo (2015) for simulation-based learning environments, with and without the use of virtual reality, directed to health professionals. We consider that the pedagogical model is sufficiently flexible to be adapted and applied to other professional contexts, namely firefighters, where training processes integrate the use of simulations as a tool for developing skills of its practitioners.

The pedagogical model integrates the characteristics of meaningful learning and the socio-cultural context, to highlight the complexity of learning and the development of competencies, indicating, in each of the six phases, the activities performed by students and facilitators:

1. Pre-activities – The tasks of the facilitators at this phase include designing the teaching process and the learning environment based on the specific objectives and characteristics of the students. The students' activities involve familiarization with the subject matter, including pre-study tasks, readings or theoretical classes.

2. Introduction – The facilitator presents the course topic and the learning objectives. The simulation concept applied in the course is explained, including its advantages and disadvantages. In this phase, students should activate previous knowledge and experiences that serve as a basis for new knowledge. Previous knowledge can be activated through discussion and sharing of experiences, construction of concept maps, among other activities.

3. Simulator and scenario briefing – This is the phase where the facilitator presents the learning environment and the scenario. This phase should include a demonstration and practical exercises using the technology. The facilitator explains the objectives of the simulation exercise, the roles of the participants and the rules. At the end of this phase, students must be familiar with the virtual environment and understand what is expected of them so that they can assume their roles and get involved in the exercise. It is important they have learned to use the simulator.

4. Scenarios – It is the main phase of the learning experience in which students participate in the simulation. At this stage it is important for the facilitator to explicitly indicate when the scenario starts and ends. The facilitator should promote an emotionally safe environment in which students are not afraid to expose their difficulties or lack of skills, so that they can be actively involved in the learning experience.

5. Debriefing – In the debriefing phase, the facilitator encourages students to carry out an analysis of the experience in order to improve their learning and future performance. Students should carry out an exercise of review and reflection on the learning process, the identification of their gaps in terms of knowledge, as well as the identification of new learning objectives. The facilitator should provide individualized feedback and emotional support to students. At this stage it is also important to compare the simulation exercise with the real world so that students can understand the differences and understand how the knowledge and skills they have acquired can be affected by the simulation.

6. Post-activities – In this phase the facilitator proceeds to a critical evaluation of the teaching-learning process, considering the facilitation process and the students' activities. He must determine whether the learning objectives have been achieved in order to develop his skills as a facilitator. From the students' perspective post-activities should correspond to the opportunity to test new knowledge and skills in a new setting or in the real world.

In the case of a course that includes more than one simulation scenario, some of the phases occur only once (pre-activities, introduction, simulator and scenario briefings and post-activities), while other phases (scenarios and debriefing) occur as many times as the number of scenarios performed (Keskitalo, 2015).

4. Evaluation of decision-making competence

Competence corresponds to the ability to mobilize, in a given context, a set of knowledge, skills and attitudes to perform tasks or solve problems (Perrenoud, 2000; Roldão, 2003; Cavaco, 2009). Problem-solving capacity to mobilize different resources, which expresse the notion of competence, can only be assessed, validated and developed when putting into action in a concrete situation (Cavaco, 2009).

The training focused on skills development requires teaching practices that involve the simulation of problem situations specific to professional activity, preparing students to act in the real context of work (Lima, 2005).

In this study we have used Effective Command (EC) methodology which was founded in 2015 with the aim of developing "thinking" commanders (Lamb, 2016).
The EC model referred by Lamb (2016) is an assessment tool designed specifically to assess command competencies in a training context. The methodology is based on the observation of competencies, called decision-making behaviours, which are demonstrated by participants in exercises developed in virtual reality simulation or real fire exercises. Decision-making behaviours focus on the specific competencies that are required for the role of Incident Commander (Lamb, Davies, Bowley, & Williams, 2014).

The decision-making behaviours that participants must demonstrate in the context of training or assessment reflect the competencies that are required to perform the following eight activities: Information Gathering; Situational Information; Effectiveness of Situational Awareness; Decision making; Plan; Communication; Command and control; Review. Each activity is evaluated according to nine specific criteria, which vary depending on the level of command. The application of this model is only completed after the debriefing conducted by the facilitator, in which the participants reflect on the decisions taken and explain the reasoning behind their decisions, allowing the facilitator to carry out the assessment (Lamb, Davies, Bowley, & Williams, 2014).

5. Methodology

The study was conducted using the action research method, which should be the choice when research addresses change processes and seek to solve real problems (Coutinho *et al.*, 2009). In this regard, it is mentioned in Amado & Cardoso (2014) that action research has as its primary objective the change and improvement of educational action.

The action research model proposed in Amado & Cardoso (2014) is developed in cycles that repeat over time until the desired improvements are achieved. The model distinguishes four steps in each cycle: 1) Problem identification and recognition; 2) Construction of the action plan or planning; 3) Implementation of the plan; 4) Reflection/evaluation.

1st Step – **Problem identification and recognition**	• Characterization of the current situation • Problem identification
2nd Step – **Planning activities**	• Training program design • Elaboration of the pedagogical guides • Creating virtual reality scenarios • Preparing the assessment tool application
3rd Step – **Plan implementation**	• Conducting pilot training course • Assessment tool application
4th Step – **Reflection/evaluation**	• Evaluation of the training course • Identification of improvements

Fig. 1. 1st Cycle of Action Research

The first action research cycle (Fig. 1) began with the characterization of the current situation, in terms of training in emergency operations management, as well as the assumptions set for the design of the refresher training course for fire officers, from data collected through document analysis, interviews and questionnaires.

The results of the diagnosis made it possible to identify and define the activities to be developed in the second stage, namely the design of the training program using the ADORA model referred by IQF (2004), the selection of the pedagogical model for the simulation-based training component, the creation of virtual reality scenarios and the choice of the competence assessment model.

In the third stage, a pilot training course was carried out with eight internal and external trainers from the Portuguese National Fire Service School. Data on trainee performance and reaction assessment were collected through a questionnaire addressed to trainees. The most relevant aspects of the development of the training activities were observed and recorded through field notes.

In the last stage, the learning outcomes and the appraisal of the trainees on the training course were analyzed, in a meeting with the members of the School team who collaborated in the study as trainers, which allowed to identify the points to improve in the next cycle.

In the second action research cycle (Fig. 2), four further steps were taken, starting with the corrections and improvements that resulted from the evaluation of the previous cycle and which were implemented in training activities aimed at eight fire officers of different fire brigades.

1st Step – **Problem identification and recognition**	• Identification of improvement proposals
2nd Step – **Planning activities**	• Implementation of improvement actions
3rd Step – **Plan implementation**	• Conducting training course • Assessment tool application
4th Step – **Reflection/evaluation**	• Evaluation of the training course • Identification of improvements

Fig. 2. 2nd Cycle of Action Research

The results of the trainees' performance and their evaluation concerning the training activities were compared with the results of the first training group, which allowed us to evaluate the consequences of the actions implemented in this cycle and signal further improvements for a future cycle.

In the study we used two groups of participants with eight trainees each, for a total of 16 participants. The first group consisted of trainers who participated, as trainees, in the pilot training course. They all had in common the fact that they were fire officers, in most cases with more than five years of experience in that role.

The second group of trainees was made up of fire officers from different fire brigades who had to attend a refresher training course in operational management, with more than five years of experience as Incident Commanders.

There were no statistically significant differences between the two groups of participants, in terms of age, qualifications, years of service and professional training. With regard to previous experience in the use of video games, simulations and virtual worlds, there were also no differences.

The research was carried out through collaborative work between the Portuguese National Fire Service School trainers and the researchers who, as participating observers, led and supported the trainers throughout the different activities.

6. Data collection and analysis

Data collection was ensured through different techniques and instruments, namely document analysis, interviews, questionnaire surveys, participant observation, and observation grid.

The analysis and interpretation of the interview data were performed through content analysis from their transcription. The quantitative data collected through the questionnaires were studied using descriptive statistical analysis. In the case of comparative analysis between the results of the training evaluation questionnaire, for the two groups of trainees, a nonparametric test for independent samples was used.

The researchers made an active participant observation collecting data on the training courses and activities carried out throughout the study by the team of the National Fire Service School trainers, including the moments of analysis and reflection.

The results of the practical evaluation of each trainee were analyzed using the SPSS version 22 software. Using the SPSS several descriptive statistics analyzes, tests of distribution normality and homogeneity of variance, parametric tests for paired samples and independent samples were performed, which resulted in the production of different tables and graphs.

7. Results analysis and discussion

7.1. 1st Cycle of Action Research

The work carried out in the initial stages of the first action research cycle culminated in the pilot training course, which took place from 16 to 19 January 2017, at the premises of the Portuguese National Fire Service School's Simulation and Virtual Reality Center (SVRC).

The simulation exercises were structured and applied according to the pedagogical model in Keskitalo (2015) and consisted of the application of the procedures inherent to each activity of the operational decision process. The exercises covered eight different scenarios, referring to incidents of urban/industrial fire, forest fire, accidents with a high number of victims and accidents involving hazardous materials.

The scenarios created using the XVR software (Fig. 3) were based on actual situations and the operational experience of the trainers' team, taking into account the learning objectives to be achieved and challenging learners to make critical decisions in complex situations.

Fig. 3. A scenario of a fire in a gas station conceived in virtual reality

Each trainee performed an exercise in a formative context and another in summative assessment context. The eight exercises were randomly assigned to each trainee, ensuring that neither performed the role of Incident Commander in both formative and evaluative exercises against the same scenario.

a) Learning Outcomes

Data were collected on the trainees' practical performance in the simulation exercises by applying the observation grid of the EC assessment tool.

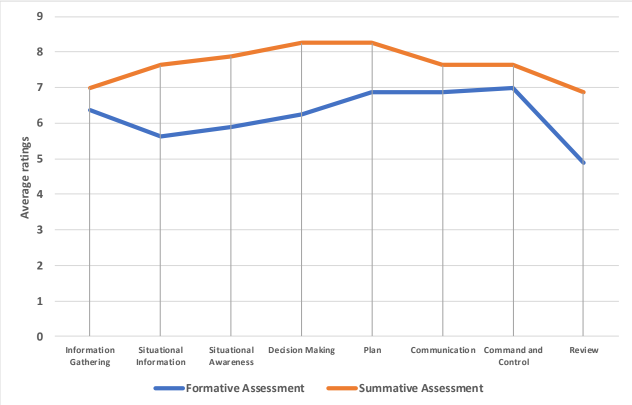

Fig. 4. Average ratings obtained by trainees in the pilot training course

Comparing the results of the average scores obtained by the trainees in the formative assessment with the ratings obtained in the summative assessment (Fig. 4), we found that in all decision-making activities the averages obtained in the second moment were higher, thus raising the hypothesis that there has been a positive evolution in the trainees' performance, meaning that training has resulted in improvement of the decision-making behaviours.

However, to conclude that the differences are statistically significant it was necessary to perform a hypothesis test. The application of the t-test for paired samples led to the conclusion that there were statistically significant differences ($p<0.05$) in the results of the two evaluations regarding the average of the final grades obtained by the trainees ($p= 0.000$) and in relation to the activities "Situational Information" ($p=0.001$), "Effectiveness of Situational Awareness" ($p=0.007$), "Decision Making" ($p=0.007$), "Plan" ($p=0.008$) and "Review" ($p=0.000$). The sense of the differences indicated that the averages of the first moment are lower than the averages of the second moment, thus it can be concluded that there was an improvement in the trainees' performance. Regarding the activities "Information Gathering"($p=0.140$), "Communication" ($p=0.142$) and "Command and Control" ($p=0.305$) there were no statistically significant differences, so we can conclude that there were no significant evolution of the trainees' performance in relation to the mentioned activities.

b) Training evaluation

The evaluation of the training course resulted from the analysis of the trainees reaction evaluation and the meetings conducted by the researchers with the trainee group and the team of trainers.

Regarding the reaction evaluation, obtained through a questionnaire applied at the end of the training course, we can highlight the main results of the trainees' perception regarding the following dimensions:

- Characteristics of the virtual reality simulator and experience of its use

The trainees recognized a greater potential of the VRS for the activities that are more dependent on the visualization of the environment that involves the occurrence, especially gathering information about the incident.
Concerning psychological fidelity most trainees considered that the virtual environment placed the same demands as incidents in the real environment, in terms of pressure factors, time, difficulties and problems, allowing them to perform actions that could be done in the real environment. Regarding physical fidelity, most trainees agreed that the simulator's visual environment adequately reproduced the actual environment and the resources usually present in an occurrence. In the domain of interaction, the movements and manipulation of objects in the virtual environment were considered natural and the manipulation of the control device (Joystick) did not cause difficulties for all trainees. In contrast, most trainees did not agree that the simulator's response time to learners' actions was adequate. Regarding the immersion experience, the trainees considered that the visual and auditory aspects created a sense of involvement in the virtual environment and the situation.

Most trainees considered the scenarios that make up the simulation exercises to be realistic. However, concerning the evolution of incidents, only half of the trainees agreed that it was realistic.

- Importance of VRS for learning motivation and decision-making competence development

Most trainees considered VRS to be very important for motivating learning and developing decision-making competence.

The characteristics that were considered most important are: allow making mistakes and exploring possibilities of action; posing problems for resolution that occur in operations in a real environment; enable communication/ interaction with other actors usually present in the incidents; possibility of identifying improvement opportunities in trainees' performance.

- Overall assessment of the training course

The application of VRS was considered by most trainees as adequate to the training objectives. Most trainees considered that the knowledge acquired in training has practical applicability in their jobs. Trainees felt more confident after training regarding decision-making competence, considering that skills acquired in training can be transferred to real situations.

The feedback provided by trainers to the learning process and to identify performance aspects that trainees could improve was considered important.

- Overall satisfaction with the training course

Most trainees indicated being Very Satisfied (50%) and Completely Satisfied (37.5%) with the application of VRS in training. The trainees noted their overall satisfaction with the training course at Very Satisfied (50%) and Completely Satisfied (50%).

The trainees also had the opportunity to express their opinion about the training activities at a meeting with the researchers, in which they stressed the importance of the exercise debriefing and the feedback provided by the trainer after each exercise.

It was also mentioned the advantage that VRS provides by creating an image of the incident common to all trainees, which facilitates understanding of what is happening and how the incident has evolved.
The evaluation and reflection of the researchers and the training team focused on the adequacy of the training proposal and the results achieved in the pilot training action. The trainers considered that the learning objectives set were met and that the methodology used, as well as the technical-pedagogical resources employed, contributed decisively to the learning outcomes achieved by the trainees.

The critical analysis also resulted in the identification of improvement proposals to be included in the next training course at exercise script level, auxiliary scripts, communication plans, documentation, virtual reality scenarios, simulator adaptation session, conduction of simulation exercises, interaction with the virtual environment, consolidation of the decision process and with respect to the structure of the practical assessment test.

7.2. 2nd Cycle of Action Research

The opportunities for improvement identified in the evaluation of the pilot training course were analyzed and validated by the researchers and the trainers' team, resulting in a set of pedagogical and technological changes. The changes were reflected in all phases of the pedagogical model, with a particular impact regarding the Pre-activities, Introduction and Scenarios phases.

Thus, changes were made to the scenarios and events included in each scenario. The scenarios were developed from a technical point of view to include more pre-programmed actions that can, at any time, be introduced by the facilitator in the scenario and be viewed by the trainees. Thereby, it was intended to make the evolution of the virtual reality scenarios depend on the trainees' decision-making.

A guide for trainers was prepared and communication plans were designed for each exercise. The sequence of events and expected actions has been set for all exercises, although each exercise contains specific events and expected actions.

The challenge of being able to present to the trainees, visually and in real time, all the actions that they decide to implement in the course of the exercise must be considered, in view of the current technological development of the simulation tool and taking into account what are the training objectives and the recipients of that training. In a training course in which it is intended to develop skills related to the management of an emergency operation, at a tactical or even strategic level, the detail of the execution of a maneuver on the ground turns out not to be relevant to the learning objectives that are intended to be achieved.

The second training course, from February 19 to 22, 2018, aimed at fire officers of different fire brigades, allowed the implementation of the changes and the measurement of the results in terms of learning outcomes and perception of trainees about the training.

a) Learning Outcomes

In the analysis of learning outcomes the same statistical procedures were used as in the first action research cycle to conclude that there was a positive evolution in the trainees' performance during the training (Fig. 5). There were statistically significant differences ($p<0.05$) concerning the average of the final classifications ($p=0.001$) and between the means of the results obtained concerning the activities "Effectiveness of Situational Awareness" ($p=0.004$), "Decision Making" ($p=0.002$), "Plan" ($p=0.001$), "Command and Control" ($p=0.026$) and "Review" ($p=0.006$). In the remaining activities, no statistically significant differences were confirmed at the two assessment moments.

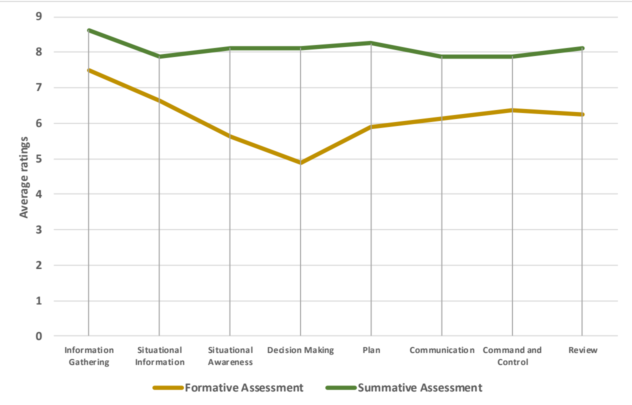

Fig. 5. Average ratings obtained by trainees in the second training course

To determine whether there were significant differences that demonstrate the effectiveness of the improvements implemented in the second action research cycle, a comparative analysis of the ratings obtained by the two groups of trainees in the exercises was performed (Fig. 6).

For the purpose of comparing results, we considered two independent groups, the group of trainees who attended the pilot training course that we designated as the “Trainers” and the group of trainees from the second training course called “Fire Officers”.

Through a hypothesis test, the results obtained in the two training courses were compared, which led to the conclusion that, in both formative and summative assessments, only statistically significant differences were observed at the level of "Information Gathering". ($t(14) = -2.260$; $p=0.040$).

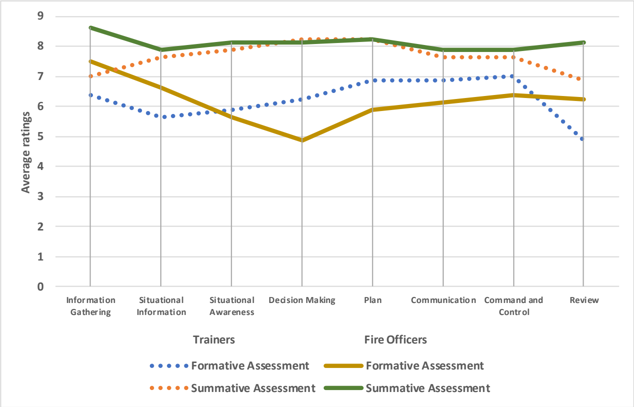

Fig. 6. Average ratings obtained by the two groups of trainees

In both cases, the second training group recorded, on average, a better rating in this activity compared to the first group of trainees. Regarding the other activities, we cannot say that there was an improvement in the performance of the trainees.

b) Training evaluation

The answers of the two training groups to the reaction evaluation questionnaire were compared to verify whether there were significant differences between the distribution of ratings on the different dimensions of analysis.

Differences between trainees’ evaluations were considered statistically significant to psychological fidelity and physical fidelity of the virtual environment, interaction with the virtual environment and concerning simulation exercises. For all issues where significant differences were noted, trainees in the second training group were given a higher rating on average, which leads to the conclusion that the trainees' perception of the points indicated improved.

In all other questions that are part of the questionnaire, the distribution of evaluations was not considered statistically different, so it is not possible to draw any conclusions about possible trends in the evaluations between the two groups of trainees.

The evaluation performed by the researchers and the team of trainers on the results achieved in this action research cycle pointed to significant improvements in simulation exercises, particularly concerning the realism of the evolution of incidents and the response time of the simulator to the actions of the trainees. Still, modifications to some scenarios have been suggested to include more actions that can be selected by trainees and an increase in interactions with trainees performing "ground" functions to minimize downtime.

It was also mentioned the need to design a larger number of scenarios because the trainees showed some ability to anticipate events in summative exercises, based on their experience with the same scenarios in formative exercises.

8. Final remarks

This study aimed to improve the pedagogical practices that involve the use of virtual reality in the training of portuguese firefighters and to improve the competencies of fire brigade command staff in emergency operations management, so that they can provide better assistance to the populations, safeguarding the safety of the firefighters under their command.

The work developed allowed to highlight a set of methodological and practical guidelines that can be considered in identical training contexts involving simulation techniques or technologies:

- The training programs must identify the knowledge, skills and attitudes acquired by the trainees during the training courses, thus ensuring that these programs are generators of competencies;
- Competencies should be acquired and developed in a formative context that places the learner in authentic situations that simulate reality and that must be related to the problems, responsibilities, and tasks inherent to the function or activity performed;
- Using virtual reality simulators allows you to create realistic scenarios that recreate situations that challenge learners, leading them to feel involved and react as if they were a real event;
- Virtual scenarios should be created, whenever possible, based on real events and their evolution should depend on the learner's decision making to better match the demands of real life;
- Training that involves virtual reality simulation should be based on a pedagogical model that systematizes the different phases to be fulfilled in the development of the exercises;
- Decision-making must be based on a structured decision model, in order to maximize the possibility of the decision being the most correct. Decision-making thus corresponds to a process and not to a specific moment in that process;
- Decision-making competence should be assessed against scenarios that represent actual incidents.

We can conclude that the study confirmed the adequacy of the training activities designed for the development and assessment of decision-making competence in emergency operations management. However, it has also shown that not all competencies are developed equally and effectively through training, which requires reflection and continued work in this field of research.

References

Aggarwal, R., Mytton, O. T., Derbrew, M., Hananel, D., Heydenburg, M., Issenberg, B., Macaulay, C., 7 Mary Elizabeth Mancini, M., E., Morimoto, T., Soper, N., Ziv, A., & Reznick, R. (2010). *Training and simulation for patient safety*. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/20693215.

Amado, J., & Cardoso, A. P. (2014). A investigação-ação e suas modalidades. In J. Amado (Coord.), *Investigação Qualitativa em Educação.* (pp. 187-204). Coimbra: Imprensa da Universidade de Coimbra.

Andreatta, P., Maslowski, E., Petty, S., Shim, W., Marsh, M., Hall, T., Stern, S., & Frankel, J. (2010). Virtual reality triage training provides a viable solution for disaster-preparedness. *Academic Emergency Medicine*, *17*(8), 870-876.

Bayouth, S. (2011). *Examining firefighter decision making process and choice in virtual reality*. Ph.D. Thesis, Iowa State University, Iowa, USA.

Blade, R. A., & Padgett, M. L. (2002). Virtual environments standards and terminology. In Stanney's, K. M. (Ed.). *Handbook of Virtual Environments: Design Implementation, and Applications* (pp. 15-27). Mahwah, NJ: Lawrence Erlbaum Associates.

Bliss, J. P., Tidwell, P. D., & Guest, M. A. (1997). The effectiveness of virtual reality for administering spatial navigation training to firefighters. *Presence: Teleoperators and Virtual Environments*, *6*, 73-86.

Blow, C. (2012). *Flight School in the Virtual Environment. Capabilities and Risks of Executing a Simulations-Based Flight Training Program*. Retrieved from http://www.dtic.mil/dtic/tr/fulltext/u2/a567288.pdf.

Cavaco, C. (2009). *Adultos Pouco Escolarizados – Políticas e Práticas de Formação*. Lisboa: Educa e UI&DCE.

Christ, R. (2006). *Preliminary Evaluation of a Novel Simulation-Based Tool for Training Rapid Decision-Making Skills* (Research Report 1847). Arlington, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Cohen-Hatton, S. R., & Honey, R. C. (2015). Goal-Oriented Training Affects Decision-Making Processes in Virtual and Simulated Fire and Rescue Environments. *Journal of Experimental Psychology: Applied*, *21*(4), 395-406.

Coutinho, C. P., Sousa, A., Dias, A., Bessa, F., Ferreira, M. J., & Vieira, S. (2009). Investigação-Acção: Metodologia preferencial nas práticas educativas. *Revista Psicologia, Educação e Cultura*, *8*(2), 355-379.

Decker S., Sportsman S., Puetz L., & Billings L. (2008). The evolution of simulation and its contribution to competency. *Journal of Continuing Education in Nursing*, *39*(2), 74-80.

Dede, C. (2009). Immersive interfaces for engagement and learning. *Science*, *323*, 66-69.

Entin, E., Elliott, L., & Schiflett, S. (2001). DMT-RNet: An internet-based infrastructure for distributed multidisciplinary investigations of C2 performance. *Proceedings of the 6th International Command and Control Research and Technology Symposium*, Annapolis, MD.

Farra, S. L., & Miller, E. T. (2013). Integrative review: Virtual disaster training. *Journal of Nursing Education and Practice*, *3*(3), 93-101.

Gillespie, S. (2013). *Fire Ground Decision-Making: Transferring Virtual Knowledge to the Physical Environment*. Ph.D. Dissertation, Grand Canyon University, Arizona, USA.

Gomoll A. H., Pappas G., Forsythe B., & Warner J. P. (2008). Individual skill progression on a virtual reality simulator for shoulder arthroscopy: a 3-year follow-up study. *American Journal of Sports Medicine*, *36*(6), 1139-1142.

Hall, K. (2010). *The effect of computer-based simulation training on fire ground incident commander decision making*. Ph.D. Dissertation, University of Texas at Dallas, USA.

Hayes, P., & Omodei, M. (2011). Essential aspects of effective simulation-based training. In R. P. Thornton (Ed.). *Proceedings of Bushfire CRC & AFAC 2011 Conference Science Day 1 September 2011*, Sydney, Australia: Bushfire CRC.

Hovancsek M. (2007) Using simulation in nurse education. In Jeffries P.R. (Ed.). *Simulation in*

Nursing Education; from Conceptualization to Evaluation (pp. 1-9). New York: National League for Nursing.

Instituto para a Qualidade na Formação - IQF (2004). *Guia para a Concepção de Cursos e Materiais Pedagógicos*. Lisboa: Instituto para a Qualidade na Formação.

Keskitalo, T. (2015). *Developing a Pedagogical Model for Simulation-based Healthcare Education*. Rovaniemi: Lapland University Press.

Klein, G. (2008). Naturalistic decision making. *Human Factors, 50*(3), 456-460.

Lamb, K. (2016). How to be an effective incident commander. *Fire & Rescue*, *102*, 22-24.

Lamb, K., Davies, J., Bowley, R., & Williams, J-P. (2014). Incident command training: the introspect model. *International Journal of Emergency Services, 3*(2), 131-143.

Lathan, C. E., Tracey, M. R., Sebrechts, M. M., Clawson, D. M., & Higgins, G. A. (2002). Using virtual environments as training simulators: Measuring transfer. In Stanney, K. M. (Ed.). *Handbook of Virtual Environments: Design Implementation, and Applications* (pp. 403-414). Mahwah, NJ: Lawrence Erlbaum Associates.

Launder, D., Lamb, K., Olde, J., & Link, M. (2015). Simulating stimulation. *Fire & Rescue*, *98*, 32-34.

Lessiter, J., Freeman, J., Keogh, E., & Davidoff, J. (2001). A cross-media presence questionnaire: The ITC-sense of presence inventory. *Presence: Teleoperators and Virtual Environments*, *10*, 282-297.

Lima, V. V. (2005). Competence: different approaches and implications in the training of healthcare professionals. *Interface - Comunicação, Saúde, Educação, 9*(17), 369-379.

Mantovani, F., & Castelnuovo, G. (2003). Sense of Presence in Virtual Training: Enhancing Skills Acquisition and Transfer of Knowledge through Learning Experience in Virtual Environments. In G. Riva, F. Davide & W. A. IJsselsteijn (Eds.). *Being There: Concepts, effects and measurement of user presence in synthetic environments* (pp. 167-181). Amsterdam: Ios Press.

Morgado, L. (2009). Os mundos virtuais e o ensino-aprendizagem de procedimentos. *Educação e Cultura Contemporânea*, *6*, p. 35-48.

Perrenoud, P. (2000). *Dez novas competências para ensinar*. Porto Alegre: Artmed.

Ravert P. (2002). An integrative review of computer-based simulation in the education process. *Computers Informatics Nursing*, *20*(5), 203-208.

Roldão, M. (2003). *Gestão do currículo e avaliação de competências*. Lisboa: Editorial Presença.

Stanney, K., & Cohn, J. (2009). Virtual environments. In Jacko's, J. A. (Ed.), *Humane Computer Interaction: Design Issues, Solutions, and Applications* (pp. 293-310). CRC Press.