Virtual and Live Simulation-Based Training for Incident Commanders

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ABSTRACT

Computer and virtual simulation-based training (CST) offer several benefits for emergency response and management preparedness. However, organizations responsible for training are often hesitant to use CST, based on cost and perceived lack of benefit when compared to live simulation training (LST). This paper investigates how CST can complement LST, and how it contributes to achieving the necessary learning objectives for level one fire and rescue service incident commanders (ICs). Data and examples come from an experimental study with students from different fire and rescue services trained in the role of the IC in LST and CST, in a similar scenario. Results show the cost and benefits of the CST implementation based on evaluations from learners, instructors and responsible managers. Participants had a positive attitude towards using virtual simulations, but the results also point to barriers regarding the suitable design of learning scenarios and implementation.

Keywords

Virtual Simulation, Simulation, Serious Games, Training, Live Training, Cost and Benefit, Use, Usability, Incident Command.

INTRODUCTION

Practice-based training is crucial in preparing new Incident commander (IC) students for their future role, allowing them to experience high presence in training handling the incidents they will face in todays' society. Practice-based training is crucial and also argued to be the most effective, even for training non-technical skills (Flin & O'Connor, 2017). Since real life expose the ICs to a large variety of incidents, the students should be able to train their role in a large number of different situations. Not only to learn the various actions they can decide to take and the expected effects of these (i.e., the tactical and technical skills) but they also need to become familiar with their role as an officer, which includes practicing situation assessments, communication and decision making during critical circumstances (i.e. the non-technical skills). In this study, we compare two practice-based training methods; live simulation training (LST) and computer-based simulation training (CST).

For many organizations and for a long time, LST and exercises at a fire and rescue training field have been considered to be the most realistic form of training, aimed to provide an experience as near to a real as possible. In addition to this, photographs, videos and tabletop models have been used to train ICs, which provide more discussion-based teaching methods. Until about a decade ago, these methods have also been the only commonly available methods for training. Due the development of virtual environments and computer game technologies, there are now computer simulation-based training (CST) tools and applications that provide new learning environments, new methods and also new possibilities to develop learning scenarios supporting IC training (Chittaro & Sioni, 2015; J. K. Lamb, Davies, Bowley, & Williams, 2014; Williams-Bell, Kapralos, Hogue, Murphy, & Weckman, 2015). Many organizations responsible for fire and rescue IC education and training have reported the unique benefits of using CST. Examples of these benefits are; training in situations that are not possible in LST (e.g. plane crash, a bomb explosion on a train), more robust training possibilities, the possibility to reuse precisely the same scenario several times and thereby assess students in equal situations, and for lower costs (Heldal & Hammar, 2017). However, several organizations are hesitating to adopt CST, even if they have access to it. To examine the benefits and limitations of CST in comparison with LST for IC training, an

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experimental study was designed, were the CST was developed based on the scenarios previously used in LST.

The broader motivation of this study was to examine how the benefits from two different environments can be combined for improved training situations. Since the users are IC students, and the technology needs to be understood and adjusted by instructors, this paper utilized CST scenarios similar and comparable to scenarios used for LST. However, the vision is to contribute to investigating added values of CST that are about practicing scenarios that cannot be trained via LST.

The comparison is based on an experimental study of a class of IC students and the return of investment is calculated for the CST and LST.

This study aimed to answer the following three research questions from IC learners, their instructors, and from responsible managers for CST and LST after experiencing both types of training:

1) Can CST replace LST?
2) What main values of CST do the learners and instructors express?
3) How may the design of a CST support or disturb training? Here we focused on the photorealism of scenarios, objects, and people.

These questions are interesting since there are several obvious similarities and differences between CST and LST. Similarities can relate to the similar learning objectives and performance of certain tasks. Differences are related to the different experiences in live or virtual environments, the nature of the different settings, elements of representations (e.g., humidity, smoke, heat, weight), activities performed during the tasks (e.g., acting in a field or with a gamepad or joystick), but also the possible outcomes may vary. While LST requires physical training fields with real objects, CST requires computers, large screens, and software licenses**.**

Both training methods are resource demanding but in different ways. While both require dedicated instructors and careful plans; the plans to conduct and assess LST require different competencies and support than corresponding CST (K. Lamb, Boosman, & Davies, 2015). Organizations responsible for IC education and training need different rules for LST and CST implementation and use (Fomin, Heldal, & Wijkmark, 2018)**.** Many have developed methods and tools to use LST in their educational activities, but at the same time they question if LST can provide the needs for IC training in this changing society, were several new challenges and risks constantly emerge (Heldal and Hammar 2017).

While the practice acknowledges the response "no" for the first question above, the question has to be asked and a discussion should begin considering the practitioners starting points and perspectives. In the same way, the usual house fire scenario may seem to provide a too simplistic training when CST delivers the possibility to train in situations not possible in LST, e.g. skyscraper fires, flooding, terrorist attacks. However, it is essential to allow users with no prior CST knowledge to experience training in a similar scenario in both LST and CST, for them to understand and point out the similarities and differences (e.g. Chittaro & Sioni, 2015; Heldal, 2004, 2018).

This paper presents an experimental study examining a class of IC students participating in training, with the focus on the role of the IC and the necessary tasks during response to an incident, here an uncomplicated house fire. According to our knowledge, this is the first systematic approach to comparing LST and CST for IC training. To make the comparison possible, the same scenario with the same preconditions was planned and developed in CST, as in the LST. At the same time, this limited the potential beneficial use of CST, where more cues (risks, complex fire and smoke behavior, and effects of different action etc.) could be added and utilized and more complex IC assessments and decision-making training could be included. In addition, we compare a limited CST with a usual LST through observations, questionnaires and interviews with learners and their instructors.

BACKGROUND

Technology resistance is not a new phenomenon, and such resistance may even be beneficial for an organization, for example, if older technologies are replaced by newer ones without enough advantages to motivate the cost in terms of learning the modern technology (see e.g. (Adner & Snow, 2010)). However, having a technology without clear reasons for it can result in non-use which also can cause confusions (Toftedahl, Hoffman, & Björk, 2012).

Today, the most common form of training for incident command is in classroom-like situations and via practice-based live training (Hammar Wijkmark & Heldal, 2015). There are already proven methods at many organizations to develop and assess these training situations, even if this may require extensive resources of training personnel, specialized facilities and well-planned live scenarios. Classroom situations like lectures, discussion based methods using table top models, video and photos are necessary to learn rules, procedures and regulations as well as live simulation were the IC student can practice interacting with a team of firefighters; to gain the necessary knowledge and acquire routines, procedures and skills. Therefore, one crucial question when introducing CST concerns its role in relation to existing training, that is, if CST can replace or complement the current training methods. Most

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executives may understand the added benefit in terms of costs, or increased quantity of training (that was even the argument for purchasing the technology), but that is not a strong enough argument to implement it more actively.

LST is necessary for the IC students to gain experiences related to physical objects and conditions and leading a team of firefighters. At the same time, LST is limited to only the types of incidents that can be simulated in these fields, due to the cost, the safety and environmental regulations related to existing objects, buildings, vehicles, etc. One building has to represent several different real-world objects, e.g., apartment house, cruise ship and workshop, and the building has to be built to hold for repeated fires several times per day, for many years. These preconditions result in sheet metal and concrete buildings that lack visual similarity to the real world object they represent. The safety regulations limit the amount of fuel (i.e. wood which is the only allowed fuel) that can be used whereby an incorrect or missing decision on action will result in the same consequence as a correct decision on action, i.e. the fire will go out in either way. The fire cannot spread and the smoke and flames cannot visualize the flames and smoke from a real house on fire (i.e. with burning plastic and other materials). At the same time, the IC training objectives include assessing the situation and gathering detailed information about the incident, by visual examination of the building and the search for information and cues in the fire and smoke behavior, the building construction etc. Such cues are very hard, and mostly impossible, to simulate and include in LST, but easy to visualize and simulate in CST (St Julien & Shaw, 2003).

Fire and rescue personnel, especially ICs, have to make many time-critical decisions in possibly life-threatening situations where their task is to protect the safety of civilians, the team, and property. Due to emergency situations being unpredictable, time-critical and high-risk situations, firefighters and ICs have to go through extensive training (Hammar Wijkmark & Heldal, 2018). Additionally, the quick development of society includes new infrastructures, transportation possibilities, housing, communications, living habits and new materials in our houses, cars, and clothes. Even the magnitude of accidents changes. At the same time as house fires and every day accidents may decrease due to preventive activities, the fire and rescue services need to develop preparedness for the more unusual and seldom occurring, complex incidents caused by man or changing climate. It is difficult to provide LST and other traditional methods for these situations. Harbors cannot be closed to practice large ship fires (Jansen, 2014), and the same fire cannot be repeated hundreds of times, in the same way, to allow to prepare or to examine a hundred firefighters in the same manner, or perform debriefing in the same manner (Chittaro & Sioni, 2015). An instructor can speak about such situations, but experiencing these in simulated environments can offer more realistic experiences or higher awareness for decision-making situations (Molka-Danielsen, Prasolova-Førland, Hokstad, & Fominykh, 2015; Polikarpus, Bøhm, & Ley, 2019).

How to train for 'the unexpected' is far from obvious. Just planning realistic enough training situations requires extensive resources of training personnel, specialized facilities, and well-planned even live-fire scenarios. Between the many benefits of CSTs, there are also additional ones, e.g. enhancing the motivation to train, providing improved insight into new situations, and allowing accessible training, traceable actions and repeatable scenarios for debriefing and evaluation of a practiced event (Girard, Ecalle, & Magnan, 2013). The latter provides a learning environment where learning from mistakes is possible, in contrast to real-life settings and LST. Being able to use CST technology for distance training is particularly attractive for many Scandinavian organizations due to a large number of small rescue services in rural locations and a large proportion of part-time firefighters and ICs. For example, 68% of the operative Swedish fire and rescue service personnel are part-time employees (MSB, 2010).

STUDY DESIGN

The study took place at the training field at the Swedish Civil Contingencies Agency (MSB) Collage in Sandö, three days in September 2017 (pre-study) and a week in October 2017 (experimental study).

The pre-study focused on collecting data to develop a CST comparable to an LST, based on observable, important learning objectives in the MSB IC course. This part also included designing and developing a similar CST for achieving the same objectives. The experimental study focused on determining costs and benefits, limitations and possibilities of CST and included thoughts about integrating it in more complex training within the same or other courses.

Pre-study

During the pre-study, six different learners from an IC class were observed in the classroom and an LST situation. In the classroom, the instructor presented the different phases of an incident, seen from the role of the IC, i.e. what the IC is obligated to do during these phases: i.e. risk assessments, assessment of the situation, decisions on actions, communication with team and command, reports etc. (see Figure 1). The understanding of these phases and the ability to act in the role as an IC in a response to an incident are the learning objectives of the classroom

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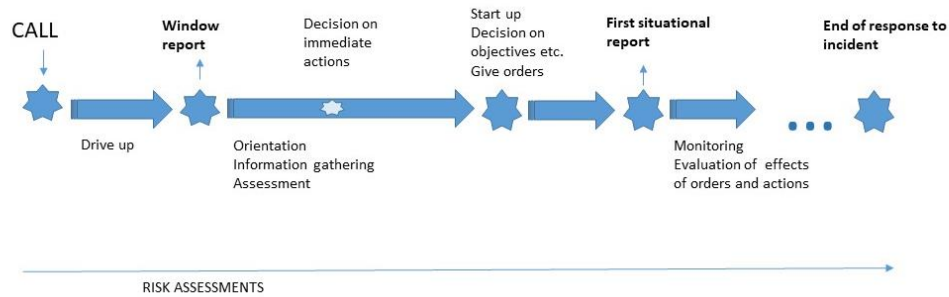lessons and first LST, and consequently the CST.

Figure 1. This figure describes the most important phases (arrows) and actions (stars), where the IC student should report to higher command or make decisions.

The confirmation of the call, the "window report" (the short report via radio which the IC gives when arriving to the scene, that confirm or adds to the information in the call) and the first situational report (the reports is give via radio, including the object affected, damage, risks, threats, objectives, actions taken and planned, the time estimate) were identified as the first main learning objectives that the ICs need to achieve in this part of the course. Observations of the theoretical lesson in the classroom and during the first LST (including AR) were performed to gather more information about this. The students and instructors were interviewed about their opinions and expectations on how CST could complement LST, and what expectations they had on a CST that would allow training for these objectives.

The scenario identified for this study was a house fire (see Figure 2). A similar CST scenario was constructed based on the observations of the LST and the interviews but also included a few new experiences. These new experiences were systematically handled (observed, discussed) in the following CST.

Figure 2. An IC student and four firefighters responding to the LST incident (right) and CST incident.

They were inspired by commonly experienced situations in real incidents, e.g. using more realistic houses, handling bystanders, journalists at the scene etc. The CST scenario was improved during several iterations and through the evaluation of IC instructors until the instructors recognized that it could provide the learning objectives necessary and similar to the LST.

Experimental study

The experimental study was planned for a new class of IC students on the same level as the learners in the pre-study. None of the learners had experienced CST before. Data for this study also was collected from managers responsible for the education, instructors and the IC students. LST and CST experiences were set up as a within groups study. The same participants, IC students, took part in experiencing both training methods, half the group first in LST and then in CST and the other half vice versa. The LST and CST training was observed by researchers, instructors and the involved managers. As we pointed out, the CST included more actors (avatars with several roles and expressions) involved in the incident, e.g. victims, bystanders, and journalists. The basic narrative for the incident, however, was the same.

Eleven different students from this class were observed during their individual training session and interviewed afterward. The six observing instructors and three observing managers were also interviewed regarding their

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observations. These instructors were not involved in the CST and had not seen or conducted CST previously. The students had to fill out a post-experiment questionnaire after each training, and a comparative questionnaire at the end. A large number of pictures and videos were taken during the training sessions. The length of the LST and CST varied between 20-40 minutes, and each interview lasted 10-15 minutes per student after each training session, and an additional 10 minutes in the end. The interviews with the instructors and managers lasted approximately one hour. The results from the questionnaires are not examined yet.

RESULTS

Return and investment

The Swedish IC level one course includes 2-5 LST sessions per student. Our first step was to investigate the LST cost/person, and if the 2-5 training occasions can be enough for preparedness? Similarly, we investigated the CST cost/person based on data from this study.

Considering all the essential elements that have to be included to obtain the objectives, for this LST, the cost was 2922 SEK/person (approx. 300 Euro), i.e. per LST session training one IC student, based on the MSB internal list of costs. The list included the internal cost of objects, instructors' hourly costs, depreciation, maintenance, service and technical staff involved, safety gear, vehicles, and cleanup etc. The corresponding CST cost/person was calculated to be 1563 SEK (approx. 165 Euro), including computers and additional technologies, technical support, development time for the virtual scenario, instructor time, license costs etc. The costs for LST are detailed in Table 1, while the costs for CST are presented Table 2.

Table 1. Cost of conducting LST for level one IC students using the house fire scenario. A training session corresponds to approximately one hour.

Resources need	Description	Cost/training occasion (one IC student)
Objects, buildings	This is the cost of this specific building used in this study. Depending on which building used, the costs differ due to deprecation costs.	SEK 380
Preparation	The cost for preparation depends on which building is chosen and if a wood fire or cold smoke can be used, or a combination of both. In this case, a small fire in a controlled pot and cold smoke could be used.	SEK 750
Fire truck	Standard cost / hour	SEK 370
Instructors	Standard costs / hour	SEK 450
Electric car used by instructor	Standard cost / hour	SEK 25
Service staff	Standard cost / hour incl Preparation and cleanup	SEK 340
Equipments Breathing app., radios, cameras	Complete BA equipment with extra air packages, for participating firefighter students	SEK 110
Vehicle	Van for student transportation on training field	SEK 265
Actors	Standard cost / hour Persons acting as bystanders or house owners. Not used in the current scenario, but often used in similar exercises.	SEK 230

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TOTAL		SEK 2922

In Table 1, the costs of only one IC student, conducting one LST session is included. Other IC students may sometimes observe a course mate's training session and take part in the feedback discussion afterward. This provides learning for them as well, but this aspect we consider equivalent in LST and CST.

Table 2. Costs of conducting IC CST using the learning center fire scenario. One training session corresponds to approximately one hour.

Resources	Descriptions	Costs/training occasion (one IC student)
Licenses	The license cost is paid per year and covers 10 licenses. Only two licenses (one for the instructor and one for the student) are required for this CST. However, the CST in this study has been conducted using three licenses, which made the movement of involved avatars smooth and more vivid, i.e. include more avatars. Hence, the cost is calculated: 3 x the license cost for 264 IC students per year, i.e. calculated based on only one CST hour per student per year, which is a very low usage rate.	SEK 284
Premises	The CST took place in an ordinary classroom, where a mirror wall separated the experiment leaders and acting instructors from the IC students. It is also possible to keep everyone in the same room. For this study room, L53 at MSB Sandö was used.	SEK 275
Computers	As the license cost, the cost of hardware has been calculated based on the total cost of 3 computers / 3 years / 264 students. Computer lifetime is estimated to three years.	SEK 3 x 16 000 /3/264 kr = SEK 60 / time
Supporting technologies	Projectors, speakers, microphones The total cost for the equipment calculated based on 264 students and a lifetime of 3 years.	SEK 15000 / 3/ 264 kr SEK 19 kr / time
Simulation technician	Standard cost/hour	SEK 450
Instructors	Standard cost/hour	SEK 450
Radios	Standard cost/hour The costs are calculated exactly in the same manner as for LST.	SEK 25
TOTALT		**SEK 1563**

The tables show that the costs of one-hour training per person are SEK 2922 for LST and SEK 1563 for CST for this scenario and to achieve the learning objectives presented earlier.

The costs do not include travel costs or coordination costs, as these should be the same as long as the LST and CST are performed at the same location. With CST, it is possible, though not yet used at MSB, to provide distributed training session were the instructors are at the collage and the students are at their fire stations around the country, which would reduce travel costs. Besides, CST has another advantage, which is nevertheless a

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significant difference, namely that students can train, e.g. by observing their own recorded training sessions or someone else's training sessions, several times if needed through the eyes of the preforming student or through a birds perspective, and recordings can include instructor comments and feedback. It is also possible to define training objectives for similar situations in CST without an instructor present.

Answers from the interviews and observations

When asking the question "Can CST replace LST?" both learners and instructors answered "no". The motivation for this is described as the as-real-as-possible-feeling of the setting, i.e. the fact that they ride in the firetruck, can interact with real firefighters, the fire is real, and they can feel the wind, rain or snow. However, all 11 students and six instructors acknowledged that the CST provided training to meet the objectives, the benefit and wished to use CST for their everyday training. Three learners, not willing to participate in the study from the beginning due to their feeling of insecurity in the IC role, were given the possibility to try out CST during their free-time at an open session one evening, decided to participate later. However, we have not included this data in the current result.

Thus, if CST cannot be considered as replacement of LST, what should motivate the extra investments? Moreover; what exactly would be needed to improve training using CST? Most learners enjoyed CST for the possibility of training multiple times in various incidents/scenarios. Having, for example, journalists and pedestrians involved in the incidents, and not only one or two persons, as in LST, was considered to contribute to more realism in the scenario. According to the learners, the CST would be especially beneficial to use in the fire stations, allowing a better understanding of the role and responsibility of the ICs, not only for the ICs themselves but also for their fellow firefighters. Another motivation to use CST is that the cost (CST cost/training session) would decrease the more training sessions it is used for and the flexibility and variation of scenarios are extensive. Having more scenarios shaped for e.g. firefighter, command and strategy level training and exercise in different incidents can result in less cost per training for CST, yet the LST cost is unchanged. For learning objectives demanding complex scenarios, LST is often not even possible, due to the limitations in live object i.e. there are no large airplanes or train stations etc. available and the cost of human resources.

To answer the question "What is the main value of CST, for learners and for instructors?" most of the interviews (with ICs and instructors) acknowledged the possibility to train in scenarios similar to real-world incidents, both for CST and LST. For CST this means the often recurring incidents that are traditionally trained in LST, but opening up the possibilities to train in incidents that are not possible in LST.

For certain situations in an incident, speaking with human-like avatars or having photorealistic vehicles, lifelike simulations were considered important. The realism of a scenario was not experienced equivalent to the photorealism of environments and objects, according to the interviews. Even if many of the current limitations due to hesitation regards the not proper or exact representations in CST, these were not hindering high presence, i.e. experiencing presence in training as presence in LST. Accurate, photorealistic representations of environments, facial expressions and exact details in buildings that are not directly contributing to the problem understanding or assessment of the situation, are not considered important in CST, according to interviews with both the learners and their instructors. However, essential signs and cues that contribute to understanding the situation, i.e. spread or direction of the smoke, information given by people involved, were considered more important than the photorealism of the buildings, flames or avatars.

According to the comment of one learner, a virtual simulation should provide basic training in the role of an IC, and prepare for handling different comparable scenarios, not precisely similar ones. Since IC students need to learn to generalize a training session to many other similar incidents, the realism of a CST should be focused more on the authenticity of the critical signs and cues leading forward the activities in the narrative, and affecting the assessment and decision making, and not the details of the narrative. Therefore, a part of the answer to the question "How may the design related issues of CST support or disturb training?" is that photorealism is not the most essential feature. Supporting situation awareness in a scenario does not necessarily mean having an exact match of buildings, people and objects, even though these issues always arise when people see CST for the first time.

DISCUSSION

In this study, we focused on examining the differences and similarities in IC training in one and the same scenario in LST and CST. This was done by developing a CST scenario based on the traditional LST scenario used during several years within the MSB IC course. We focused on the student's experience of realism and presence during training and the instructor's and manager's reflections after observation of training sessions. Even though the students expressed a positive attitude and wish to increase the use of CST and acknowledged that the training fulfill the training objective, it is clear that the traditional methods of training are considered as realistic-as-

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possible, fulfilling the course objectives, and there is no pressure to cut costs hence not stressing the need to implement CST. At the same time, the ICs of today and tomorrow need to be prepared for unusual, unexpected and complex events, which LST cannot provide training for (Heldal & Wijkmark, 2017).

The strategic question that needs to be answered by management, responsible for IC training, is related to the course objectives, not primarily to the method of training (Fomin et al., 2018). If the purposes include the ability to handle the IC role in complex, unexpected, quickly changing incidents, the strategic way forward would be to build knowledge and experience in using CST as a complement to LST.

The next step of this study will be to investigate in more detail the keys for successful scenario design in CST, which cues and realistic details (e.g. visual and audial detail, live simulation counter-play, etc.) should be included in the virtual scenarios to strengthen the student's presence and possibility to train the specific non-technical skills in the role as an IC, i.e., situation assessment and decision-making.

For CST, there are more values than the cost to explore in detail. The learning outcome would be valuable to study in more detail. One challenge would be to measure the learning and validate the learning goals since the real achieved knowledge and competence can only be viewed in the real world incident. When using CST, the validation of the learning cannot be measured or examined via LST, since LST cannot provide the complete situation (with all cues and responses to decision).

CONCLUSIONS

To prepare ICs for the surprising, uncommon or unfamiliar situations, the next step in training development needs to involve CST, because of LST limitations. Since CST involves relatively new technology and method for IC training, it would be suggested that organizations like MSB would continue implementing CST for the basic training suitable for this, i.e., with objectives applicable to it, to experience and gain not just economic benefits, but also the user, instructor and scenario design experience for CST. This is needed as a foundation for the further steps of implementing and developing CST. To achieve and document further benefits of CST, more competence development and instructor involvement would be suggested. This would also benefit further explorations on how CST can compete for LST and other traditional training.

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