Augmented and Virtual Reality (AR/VR) and Artificial Intelligence (AI) Technology in Systematic Inter-Professional Crisis Management Training

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Abstract

The technological transformation has enabled innovative changes in operational processes and services. Immersive technologies, specifically Augmented Reality (AR) and Virtual Reality (VR) training has been used for many years with excellent results to train e.g. astronauts, pilots, paramedics, and military personnel. Emerging technologies, such as Artificial Intelligence (AI), present even greater opportunities when it comes to making our crisis management systems more intelligent, secure, and effective.

At present, the crisis management field is dominated by conventional exercise methods, for example when participants gather to discuss or simulate a full-scale scenario (such as table-top exercises). Consequently, exercises that present participants with realistic challenges under time pressure are rare, if they even exist. Other problems identified in earlier research are, for example: inadequate assessment of the effectiveness of training; difficulties in defining a suitable training context or content; providing timely and relevant feedback to participants; and transfer of "lessons learnt" to future incidents.

With this study we aim to design an experimental testbed for the purpose of conducting systematic comparisons of various configurations of simulation exercises, using novel tools and procedures (such as AI, VR, AR). The baseline for comparison will be traditional time- and space-dependent (i.e., field) exercises. Measured variables fall into the categories of situational awareness (SA), decision-making, communication, inter- and intra-team dynamics, and leadership. The main dependent variable will be learning outcomes. Our main hypothesis is that using novel tools and technologies to support systematic crisis training and exercises on crisis management will have a positive effect on intermediary processes as well as learning outcomes.

1 Introduction

The current Covid 19 pandemic has provided an extra opportunity to reflect on how future training and preparedness for pandemics, emergencies and disasters might be improved upon [1]. Integrating cutting-edge technology to improve cost effectiveness in training, quality and outcome goals can be achieved using virtual and augmented reality platforms (VR/AR). Several emergency management and response organisations are currently exploring its use as part of their training and education programs [2] [3]. Training for emergencies, including field exercises, often necessitates a combination of classroom work, table top training, and the use of mannequins or real life actors to recreate disaster scenarios, with the latter often a resource-intensive and expensive but critical part of the programme [4]. Improving the effectiveness of emergency response training requires the ability to simulate a high stress, high fidelity environment with realistic distress factors.

Novel ways to reduce barriers while maintaining the quality and realism of training are continually being explored. Leveraging new or maturing technologies such as AR/VR should be considered, as recent studies have suggested that a well-designed, full immersion AR/VR environment for mass casualty training can provide similar learning outcomes and at a significant cost savings [5] [6] [7]. Other advantages of VR include instant feedback on disaster training performance. Live simulation drills necessitate the need for referees to supervise and assess each student on a 1:1 basis during scenarios. Reliably recording data points has been problematic as it depends on manual data collection in a chaotic environment, whereas an AR/VR environment automates the process, providing immediate data analysis and feedback to students [8].

Furthermore, highly realistic and interactive AR/VR platforms have the additional ability and benefit of running simultaneous and consistent, standardized scenarios and these attributes are ideal for forming a standardized testing and competency assessment tool [8]

[9] [10]. Technology has long been used to increase efficiency, reduce costs and improve existing processes in other fields, but is now particularly pertinent in the emergency response field [9] [11]. However, addressing challenges that impede resilience remain a critical research gap [12].

The consequences of global warming (such as extreme weather conditions), natural disasters, and terrorist attacks are just two examples of phenomena that have put major and complex incident training and exercises at the top of the agenda of government agencies worldwide. The last months' hostilities in eastern Europe, with the Russian invasion in Ukraine, makes preparedness an even more current issue in Norway and the Nordic countries as well. In extreme events, multi-disciplinary and multi-professional teams are required to function together cognitively [40]. The fact that crises and major incidents are rare means that few people in the organizations have actual experience of handling them [13].

At the Inland Norway University of Applied Sciences, two faculties (the School of Business and the Faculty of Health and Social Sciences) have started a unique cooperative effort in designing education programs that foster interoperability crisis management, emergency medicine and public preparedness. This is exemplified through a joint, new master course that started early April this year.

In planning and executing this course, an interfaculty project group with researchers and lecturers worked together to provide an interdisciplinary curriculum centered on emergency and crisis management. This project aims not only to widen the perspective in the field, but also to build an AR/VR/AI research group in the combined fields of crisis management, emergency medicine, trauma and stress psychology and public preparedness on both the tactical and operational level.

A new physical facility of around 300 square meters is under construction at one of the INN University campuses, Campus Rena, that will be used as a venue for large-scale, cross-disciplinary, crisis management training and exercices. Naturally, state of the art technological solutions within AR/VR and AI will be installed and in operation at the facility - and will be used for automated data collection (sound, image, video, etc.) in future research projects.

2 THEORY AND HYPOTHESES

2.1 TECHNOLOGY

Studies of ongoing usage, effects and learning outcomes from computer-based VR/AR training, seem to be rare, proposing that computer based emergency response training are urgent issues for future research [14]. Dynamic decision-making (DDM) is interdependent decision-making that takes place in an environment that changes over time either due to the previous actions of the decision maker or due to events that are outside of the control of the decision maker. In such situations the system changes over time, a factor the decision maker must take into consideration [15]. Brehmer included an additional aspect, namely that decisions need to be made in real time [16]. This factor added an extra dimension to dynamic decision making, as the decision maker has to consider the dimension of time explicitly. It is not enough to know what should be done, but also when it should be done.

Artificial intelligence (AI) refers to computational technologies that sense, learn, reason, and act following the way humans do [17] [37]. AI has the capability to provide autonomy and flexibility in a dynamic and multi-criteria decision making environment as crisis management constitutes [38] [39]. The application of AI to support real world decision making (for example in strategic management and crisis management) is still in its infancy, and researchers disagree somewhat when it comes to assessing the usefulness and efficacy of AI tools in this respect [37] [39].

AI is, as far as we know not yet described in the literature regarding decision support in interoperability training and task management in emergency response settings.

In summary, we know very little about the effectiveness of using computer-based exercises (i.e., software and hardware tools) to support crisis and major incident management training. The proposed project provides a synthetic and critical review of state-of-the-art VR/AR applications for emergency response training in simulated environments, and facilitate further advancements in both research and practice in this area. To the extent that AI applications are under development, and pilot and prototype systems are on the verge of being introduced as tools for training and exercises in crisis management, this will also be included in a review.

2.2 TRAINING AND EXERCISES

Training has long been a fundamental concern in organizational contexts. Organizations rely on learning strategies, training technology and development efforts to prepare their workforce. Training is a key and mandatory component in developing capabilities for emergencies [18].

More specifically, emergency management training is intended to develop people's capacity to respond to the new and atypical demands presented by a disaster, as well as developing norms of carrying out a job or exercising a specific skill [13]. A methodology for effective simulation-supported education, training and exercise built on a meta-analysis of training and development studies is developed (Figure 1) [19]. Emergency training is a statutory requirement and therefore needs to be systematically organised.

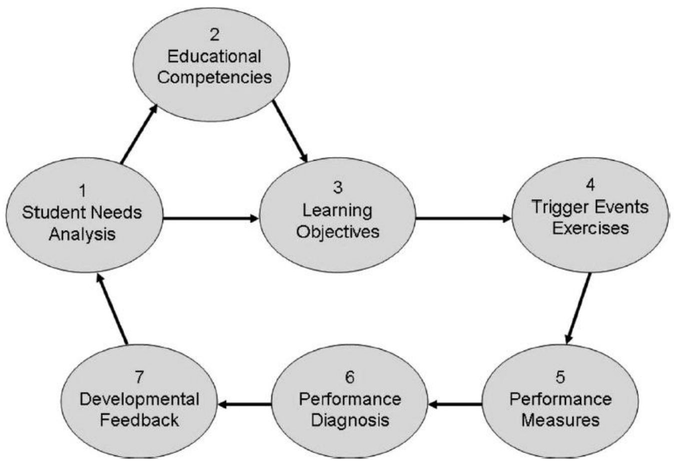

Figure 1: Stages for the successful implementation of simulation-based training in management education [19] [32:565].

2.3 CONTROL VARIABLES

In their typology of extreme contexts, Hannah et al. [20] review several variables that may affect the perception of level of extremity of, and in turn the response to, a crisis management situation. The contextual variables encompass location in time, magnitude and probability of consequences, physical or psycho-social proximity, and form of threat. As moderating variables that may attenuate the perceived level of extremity, they list psychological, social and organizational resources. As moderating variables that may intensify the perceived level of extremity, they list time pressure and complexity of the situation. In an experimental design these contexcutal variables may be controlled for by deliberate manipulation (in order to examine the effects of systematic variation of the context), or by randomization (in order to neutralize the effects of context).

We may also have to control for variables that pertain to individual differences, such as domain experience, cognitive ability (IQ), personality ("Big Five") and cognitive style (intuitive and analytic), that all have the potential to affect the decision making process as well as task performance and in turn learning outcomes [21]. These variables may be controlled for by collecting data through questionnaires and perform statistical control by including the variables in the regression equation. Effective control may also be performed by randomization in an experimental design.

Other variables pertain to various structural and processes phenomena that take place in a crisis management situation, for example:

2.3.1 Shared Situation Awareness

Shared situation awareness (SSA) concerns having an adequate overview of the situation - how it has arisen, how the situation is now, and what are possible and probable future events. SA being shared, concerns the extent to which this information and the proper understanding of it, is common and equal between the actors [25] [33]. One of the most promising applications of novel technologies, such as AR/VR and AI, to crisis management, will be strengthen actors' situation awareness. Both the degree of "sharedness" as well as the accuracy and timing of SA may be enhanced with novel technology tools [37] [38].

2.3.2 Decision Making

Decision making and decision processes under crisis is characterized by great time pressure, high uncertainty, and high stakes [23]. Gary Klein [28] [29] [30] has developed a model that encompasses both intuitive and analytic aspects of decision making in naturalistic settings; the Recognition Primed Decision (RPD) model, which describes decision making in operational & emergency situations quite well. By using novel technological tools for decision support, it is reasonable to assume that decision making will improve in both speed and accuracy [39].

2.3.3 Organization Structure

The configuration of a command and control organization – and the chain of command – concerns the coordinated division of roles, tasks and responsibilities between the organization members – whether the members are working alone or in work groups and teams [31] [26] [40]. A central parameter is the degree of the organization being centralized & hierarchical vs. distributed & networked. Another parameter is whether the command decisions are given as direct orders or as command concepts – command by intentions [24]. Both AR/VR and AI technologies may prove to have substantial benefits when it comes to supporting a decentralized, networked command organization, that is both flexible/agile in response to unexpected threats as well as efficient when it comes to respond swiftly and decisively against more familiar forms of hostilities.

2.3.4 Communication

Communication is related to the choice of communication medium (such as email, radio, or face-to-face), as well as how to use available media efficiently and effectively. This applies whether communication occurs internally between actors inside the command organization, or when addressing the media and the public [27]. An interesting avenue opens up for exploring whether novel technology, such as VR and AR, can avoid – and mitigate the consequences of – misunderstandings during tactical, operational and strategic communication during crisis management [27] [33].

2.4 Hypothesis

Based on the preceding theory for implementation of AR/VR and AI in simulation-based training, we formulate a main hypothesis:

> *H1: It is a positive relationship between employing VR/AR technology and AI tools to training on major incidents for first response units (Health Services, Law Enforcement and Fire/Rescue), and the measured effectiveness of such training.*

That the training is systematic means that one follows the process model, step-by- step, as recommended in [19] and [32]. Training effectiveness includes learning in the form of knowledge acquisition, as well as a (permanent) change in behaviour that is consistent with an improved ability to perform tasks relevant to preparedness and management.

We do not intend to formulate any hypotheses concerning the relationships between any of the control variables, and employing VR/AR and AI to support the training process. Any such relationships will be open to explorative research.

3 Methodology

Interprofessional and multi-agency training and working are highly complex tasks. The output from the project has potential to explore and improve emergency response training while applying AR/VR, including support from AI. Thus, it is our ambition to examine the effectiveness of training in a more structured and systematic manner than has been the tradition until now. With our focus on ICT-supported training and exercises, we intend to use automated data collection methods to supplement the traditional questionnaire-based and qualitative approaches. This triangulation will provide us with more data of better quality, and allow for more valid and reliable conclusions [41].

By using a true experimental setting (with control by randomization), we will examine causal relationships between independent and dependent variables. At the outset we will attempt to compare the effects of introducing digital tools in traning and exercises by setting up experimental groups that use the tools, and control groups that do not use any digital tools. We will also experiment with varying configurations of the tools.

ICT tools will enable access to a richer reservoir of data to use in assessment and feedback from training sessions. For example, data may be collected automatically and unobtrusively (without conscious intervention from the trainee). Such data may be more reliable, collected more frequently, in larger volumes, and with less costs, than “manually” collected data. Data from VR/AR technology, and the use of AI tools, will digitally map communication, interaction, actions, task management and decisions made by trainees. This will be an innovative and different way to evaluate and assess performance and training effect than the conventional and traditional way to evaluate scenario trainings, with assessments from the trainees themselves, and external observers.

Measures of performance, effectiveness and learning ourtcomes will be developed within the project to assess stages 5 to 7 in the model in Figure 1 [32], supplemented with metrics for control variables [21].

4 Impact and Implications

This project will aim to create and validate an integration for training and exercises in VR/AR and assessment of AI as decision support in complex critical incidents, wheter in the First Response Units or other organizations concerned with public security and safety (such as the defence).

The research is also important to suggest fields of public innovation on technological solutions for more integrated and effective responses from emergency response units and organizations when an incident demands high stake coordination and cooperation. It is the ambition of this project to develop a methodology both to apply Information Communication Technology (ICT) to such training, and to assess the effectiveness of the training using both quantitative and qualitative methods. We expect a long-term effect to be improved quality of training and exercises in emergency responses. In addition to computer-based VR/AR training within and across the emergency response organizations, it is necessary to explore the possibilities in AI technology for quick and timely decision support in the complex nature of major emergency incidents. Time is a highly critical factor in management in these situations and the decision- making process is a crucial part of the management.

We will test AI tools integrated in the computer-based VR/AR training exercise modules to test the feasibility of AI in these incidents and situations. AI may accelerate the decision-making process and support fast information sharing across the units and facilitate a precise and quick shared situation awareness (SA). The project has a potential for several long-term effects of benefit to society, including significant improvements in both emergency incidents training and practices in the emergency response organizations. The project may provide useful data for innovation and development of Information Communication Technology (ICT) tools and decision support tools to be implemented in the organizations.

Through the joint efforts of the projects group members from complementary fields of crisis management and communication, psychology, human factors, information technology, emergency response organizations and emergency medicine we aim to develop systematic, cross-sectional high-quality training and exercises for high-stake major incidents to enhance situation awareness, decision making, communication and interoperability in and across the First Response Units.

5 Conclusions

In Norway, cross-sector exercises focused on major incidents take place once or twice in a four- year period. Substantial time is spent on planning larger exercises. Having participants from several sectors to attend an exercise, in order to have a collaboration exercise, takes even longer time to plan. There is noe reason to belive that the conditions for conducting large-scale collaboration exercises are any better elsewhere [34] [35] [36].

It is our ambition with the project that our results could be applied to improve the practice and effectiveness of such collaborative training. By using ICT-tools, hereunder VR/AR and AI tools, for systematic management training, the society can save enormous resources by being able to reduce the (waste of) time and resources spent on exercise planning, and still be able to conduct more frequent and more focused exercises, at lower costs, and with better learning outcomes.

It is also an ambition to gather experiences with novel methodology that may benefit subsequent R&D projcts.

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