The Impact of Practical Skills on Improving the Servicemen's Preparedness to Act in Case of Radiation Contamination of the Area

Petro Dziuba*, Serhii Burbela, Vitalii Zhuravel, Bohdan Marchenko and Kostiantyn Verheles

Department of Combined Military Disciplines, Bohdan Khmelnytskyi National Academy of the State Border Guard Service of Ukraine, 46, Shevchenka Str., 29000, Khmelnytskyi, Ukraine

Abstract: The servicemen's practical skills to respond to threats of chemical, biological, radiological and nuclear attacks, as well as the ability to make effective decisions are necessary for the implementation of effective targeted actions in the face of military threats. The aim of the article is to identify the impact of servicemen's decision-making skills on their preparedness to act in case of radiation contamination of the area as well as an analysis of the opportunities of skills development in the educational simulation environment. The research employed such empirical methods as: educational experiment, testing, survey, quantitative assessment, and qualitative analysis. The study of causal relationships between servicemen's decision-making skills under Contaminated Remains Mitigation System CRMS conditions and their preparedness to act under conditions of radiation contamination made it possible to identify a set of decision-making skills that affect high, medium and low servicemen's preparedness to act under the chemical, biological, radiological, and nuclear (CBRN) attacks. The authors developed and tested a virtual reality training simulator for training decision-making skills in a simulated environment of potential threats using the Zaporizhzhia Nuclear Power Plant (NPP) situation as an example. The results of the assessment of students' knowledge after the educational experiment showed that simulation training in virtual reality was more effective than training using educational video content. The students of the experimental group (EG) showed a 13.2 points better result (90.6 points) in decision-making accuracy than the students of the control group (CG) (77.4 points).

Keywords: CRMS threats, decision making skills, virtual reality, simulation training, servicemen, security, defence.

1. INTRODUCTION

Creating a pool of trained emergency responders is a key current objective in view of the military conflict in Ukraine and the threat of CBRN attacks [1]. The training of military specialists should be carried out in view of the nature of current threats to national security, including: 1) a high probability of the enemy using tactical nuclear weapons; 2) the achievement of a critical level of terrorism by Russia using accidents (destructions) of nuclear industry facilities and critical infrastructure facilities; 3) an increase in the use of unknown chemical asphyxiant substances [2].

In view of the growing problems that threaten humanity, the search for ways to ensure international peace and security becomes extremely urgent [3]. The potential destruction of the Zaporizhzhia NPP located in Ukraine is of serious concern to both the local and international community. A nuclear disaster at such a facility would create a serious threat due to the emission of gamma radiation — a form of ionizing radiation that could lead to devastating consequences for the health of the population and the environment. Understanding the risks of gamma radiation contamination is critical to disaster preparedness and relevant response [4]. CBRN emergency preparedness is an extremely complex task involving a large number of public authorities and private actors at national, regional, and local levels [5].

Disaster management requires innovative solutions, especially in the use of technologies for rapid response and mitigation. New solutions, protocols and technologies should be tested in an environment as close as possible to the real one. Real catastrophic conditions are the best testing ground. However, such conditions are extremely unpredictable and it is not easy to implement them in the process of methodological research [6]. One of the main requirements for highly effective emergency response training is a well-prepared and reliable scenario, which is implemented in the conditions as close as possible to real ones. Modelling CBRN hazards, especially biological and radiological, is very complex, expensive, time-consuming, strictly regulated and in many cases, like nuclear, almost impossible [7]. In this regard, there is increasing interest in finding innovative opportunities for conducting scientific experiments and training emergency responders. Special attention is paid to modelling in an immersive environment. Modelling and simulation, combined with empirical data derived from lessons learned from the past, can be a valuable source of factual information. This information will help

*Address correspondence to this author at the Department of Combined Military Disciplines, Bohdan Khmelnytskyi National Academy of the State Border Guard Service of Ukraine, 46, Shevchenka Str., 29000, Khmelnytskyi, Ukraine; E-mail: petrodz.stateborderguard.ua@gmail.com

to make effective and efficient decisions, as well as to develop response measures, considering the contextual factors of the affected area and the specific scenario of the natural disaster [8].

Today, virtual, augmented and augmented reality technologies are widely implemented in the defence system to acquire skills in difficult conditions. An immediate benefit of training with the involvement of these technologies is the ability to effectively visualize various elements and techniques, assess threats/targets, determine spatial proximity, and receive instructions from management [9]. Knowing and understanding the specific crisis situation is key to successfully preparing for a CBRN incident. Training for a specific CBRN mission requires the development of an in-house learning experience that implements a combination of “hard” and “soft” competencies in a specific setting [10].

The aim of the article is to identify the influence of military servicemen’s decision-making skills in the face of CBRN threats on their preparedness to act in case of radiation contamination of the area as well as an analysis of the opportunities of skills development in the educational simulation environment.

The aim involves the fulfilment of the following research objectives:

- Study the cause-and-effect relationships between decision-making skills of servicemen and their preparedness to act in case of CBRN emergency;
- Determine the configurations with a high, medium and low level of influence on the servicemen’s preparedness for the conditions of radiation contamination of the area;
- Develop a virtual reality (VR)-based educational simulator for training decision-making skills in a simulated environment of potential threats;
- Conduct an educational experiment in a virtual laboratory aimed at developing students’ practical skills, such as technical knowledge, operational responsiveness, improving team structure and effective collaboration in dynamic CBRN scenarios;
- Compare the test results of the CG and the EG students, confirm or refute the expediency of using simulations in the virtual space for the development of practical decision-making skills in the face of CBRN threats.

2. LITERATURE REVIEW

The current geopolitical environment and strategic uncertainty caused by asymmetric and hybrid threats require further development of practical training in realistic settings. Limiting the frequency of training may prevent first responders from achieving the desired level of preparedness because preparation for potential threats is essential to high-level preparedness and safety [11]. CBRN protection is a very diverse set of tasks and steps, but it can be divided into five main functional areas: 1) detection of a CBRN incident or contamination; 2) information management: collection, processing and transfer of collective intelligence, protection of equipment and materials; 3) risk management; 4) provision of adequate medical care to people affected by CBRN hazards. The key to effectively increasing the CBRN protection potential is continuous and targeted development according to a well-structured concept [12].

According to [13], one of the key aspects of the safety and success of first responder operations is adherence to all safety procedures and suggested protocol during an intervention. However, teaching approaches based on in-class lessons and multimedia learning materials may not be particularly effective for teaching practical skills and procedural behaviour. According to [14], emergency responders should practice in realistic settings to bridge the gap between theory and practice. Researchers Yamamoto and Altun [15] believe that serious games and VR simulations are able to improve problem-solving skills and the quality of learning and allow training of practical operational skills in a controlled safe environment without risks to students’ life and health [15].

Bucata *et al*. [16] believe that VR can provide a realistic, immersive learning experience that prepares soldiers for a wide range of situations, including combat operations, peacekeeping operations, and disaster response. VR can also be used to improve situational awareness and develop real-time coordination skills, which can help troops be better prepared and more effective in real situations. According to[17], specialized VR products can be useful for military institutions to develop combat and tactical skills of personnel in real missions.

In addition to being immersive, VR provides a better platform for teaching disaster management strategies by providing a realistic experience to the user [18]. According to [11], VR for CBRN training offers the potential to enhance and accelerate learning and can serve as a valuable addition to existing disaster and CBRN training curricula and programmes. A VR system can provide several advantages: 1) basic training scenarios can be easily recreated in VR; 2) new scenarios can be easily added to the system; and 3) complex scenarios can be created. Advanced feedback mechanisms such as brain-computer interfaces, tactile/olfactory feedback, and advanced artificial intelligence (AI) can be integrated into immersive virtual environments to provide a more realistic learning experience [19].

The speed and accuracy of training data transfer are critical parameters for evaluating VR technology and its effectiveness. Interactions in virtual reality are dictated by many aspects that help to better prepare the user for the real-world scenarios and tasks that VR systems simulate [20]. It is necessary to identify critical factors that must be taken into account during the development of the training process in order to ensure the most favourable conditions for training and, therefore, its effectiveness [21]. The system should be designed in such a way that it can be flexibly changed depending on the learning objectives and managed by applying different risk scenarios [22].

The literature review showed that the VR use in education is a powerful tool for preparing specialists for modern geopolitical challenges and asymmetric threats. VR tools enable creating realistic learning conditions that contribute to the development of practical skills and increase readiness for real scenarios. The development of methods for evaluating the effectiveness of VR training is a key aspect of the further development of this technology for military and civilian purposes. However, the possibility of using simulation training in a VR environment for the development of servicemen's practical decision-making skills in the face of CBRN treats requires a more thorough study.

3. METHODS AND MATERIALS

3.1. Research Design

In January 2024, an online conference Training of CBRN Specialists: Current Problems and Opportunities was held via Zoom. Teachers of higher military educational institutions of Ukraine and students of the National University of Civil Defence of Ukraine took part in the conference. The participants of the conference were invited to take part in a further study aimed at identifying the impact of simulation training in virtual reality on the accuracy of decision-making in the context of CBRN treats.

The research was conducted in 2 stages accompanied by three moderators, teachers of the National University of Civil Protection of Ukraine, developers of the VR Simulation in the Face of CBRN Threats course.

The first stage (January 2024) involved a survey of experts in order to identify key decision-making skills that affect the servicemen's preparedness to act in CBRN emergencies. The experts were asked to rate the influence of decision-making skills on the preparedness to act in case of radiation contamination of the area in the range of 1 to 5 points. Causal relationships between servicemen's decision-making skills under CBRN conditions and their preparedness to act in case of radiation contamination of the area was studied using the method of qualitative comparative analysis of fuzzy sets (fsQCA).

The second stage (March - May 2024) provided for an educational experiment aimed at investigating the effectiveness of using simulations in virtual space for the development of practical decision-making skills in the context of CBRN threats. Two groups were formed — the EG and the CG, which were made up of students of the National University of Civil Protection of Ukraine. The educational experiment was carried out for 3 months and included 20 training sessions. The CG participants were given video content on the Skillshare online platform (skillshare), as well as test tasks in a mobile application developed on the SkillzRun platform (https://skillzrun.com/). The EG participants were trained in a VR laboratory. The EG students also had access to the test tasks in the mobile application. The training scenarios were developed considering the potential threats to Ukraine in the event of an explosion of the Zaporizhzhia NPP and large-scale pollution of the local environment.

3.2. Sampling

The participants of the conference were provided with information about the goals and objectives of the planned educational research and were invited to participate in it. Each participant of the conference was given access to online registration in the research in two directions — experts and students. The registration form was filled out by 11 teachers of higher military educational institutions of Ukraine and 46 students of the National University of Civil Protection of Ukraine. In fact, 34 teachers and 98 students participated in the research (Appendix A, Table **A.1**, **A.2**). The study group was divided into a control (49 people) and an experimental subgroup (49 people) by random selection.

3.3. Research Methods

The research employed such empirical methods as experiment, testing, survey, quantitative assessment, and qualitative analysis.

The Fs-QCA3.0 software was used for a qualitative comparative analysis of the relationship between variable conditions (skills) and variable results (readiness) from the perspective of configurations, as well as for demonstration of the dominant conditions under which skills affect the servicemen's preparedness to act.

Qualitative fuzzy set comparative analysis (QCA) is an effective method for studying complex causal relationships and multiple interactions. It is based on the research methods of Boolean algebra and set theory, which allow analyzing the configurations of various influencing factors. In QCA, Boolean algebra is used to determine combinations of variables that lead to expected outcomes. Set theory, in turn, is used to establish the relationship between the conditions leading to the result through the set-subset relationship [23]. An important advantage of QCA is its orientation to the result and the possibility of applying the conditions necessary to achieve the desired results. The method also allows you to combine various conditions to produce a particular result [24]. As your method of qualitative comparative analysis of fuzzy sets allows you to apply a set of conditions that lead to a certain result, it was used in our studies for the set of skills of military personnel that affect high, medium, and low readiness to act in conditions of radiation contamination of an area.

The method of qualitative comparative analysis of fuzzy sets (fsQCA) was used to identify the relationship between the decision-making skills of servicemen under CBRN conditions and their preparedness to act in case of radiation contamination of the area. The procedure for qualitative comparative analysis of fuzzy sets consisted of the following main stages: configuration model design (Figure **1**), construction of empirical data, calibration and data analysis, reporting, and interpretation of results (Tables **1-4**).

The study of cause-and-effect relationships between decision-making skills of servicemen under CBRN conditions and their preparedness to act in case of radiation contamination of the territory included the following variable conditions: 1) decision-making skills in the field of detection of CBRN incident or contamination (C1); 2) decision-making skills in the field of information management (C2); 3) decision making skills in the field of providing individual and

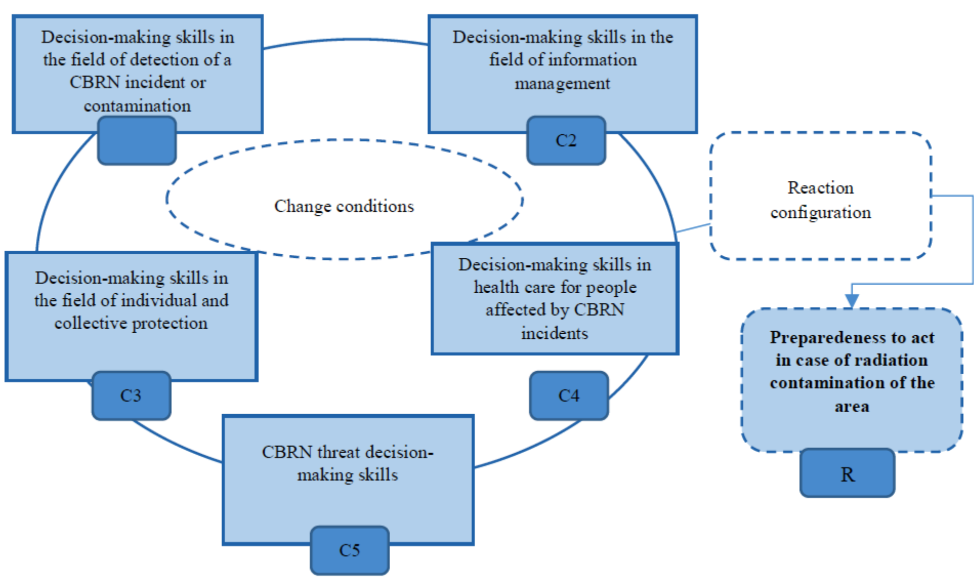

Figure 1: Research model of configuration analysis.

*developed by the author.

Table 1: Results of the Statistical Analysis of the Variables of the Research Conditions

Variable Conditions	Conventional Designation	Mean	Standard Deviation	Minimum	Maximum
Decision-making skills in the field of detection of a CBRN incident or contamination	C1	3.916	0.840	1	5
Decision-making skills in the field of information management	C2	3.737	0.539	1	5
Decision-making skills in the field of individual and collective protection	C3	4.351	0.830	1	5
Decision-making skills in health care for CBRN-affected people	xC4	4.184	1.061	1	5
CBRN risk decision-making skills	C5	3.735	0.263	1	5

*developed by the author.

Table 2: Reference Points of Calibration to Variable Conditions and Result

Variable Conditions		Full Membership	Reference Point of Intersection	Complete non-Membership
Variable conditions	C1	3.24	3.09	2.93
	C2	3.61	2.91	2.21
	C3	3.95	3.11	2.27
	C4	3.71	2.93	2.15
	C5	3.56	3.14	2.71
Result variable	R	4	3.20	2.41

*developed by the author.

Table 3: Conditions of the Servicemen's Preparedness to act in Case of Radiation Contamination of the Area

Variable Conditions	High and Medium Levels of Preparedness to act in CBRN Emergency (R)	Low Level of Preparedness to act in CBRN Emergency (R)
C1	0.814	0.534
C2	0.835	0.323
C3	0.912	0.421
C4	0.910	0.531
C5	0.846	0.361

*developed by the author.

Table 4: Analysis of Configurations Affecting the Level of Servicemen's Preparednessto Act in CBRN Emergency

Variable Conditions	High and Medium Preparedness to act in CBRN Emergency(R)					Low Level of Preparedness to act in CBRN Emergency (R)		
	S1	S2	S3	S4	S5	H1	H2	H3
C1	●	•	•	⊗	•	●	•	•
C2	●	⊗	●	●	•	•	⊗	●
C3	•	●	•	●	●	⊗	⊗	⊗
C4	●	●	●	•	●	⊗	⊗	⊗
C5	•	•	⊗	•	⊗	⊗	●	•
Consistency	0.902	0.908	0.905	0.903	0.901	0.905	0.911	0.917
General consistency	0.903					0.911		
General coverage of the model	0.531					0.493		

"●" and "•" indicate that the condition exists, "⊗" indicate that the condition does not exist; "●" indicate the basic state, "•" indicate the boundary state; "-" indicates that there is no direct causal relationship with the result.

*developed by the author.

collective protection (C3); 4) decision-making skills in the field of providing medical care to CBRN-affected people (C4); 5) decision-making skills in the field of working with CBRN treats (C5). The variable result was preparedness to act in case of radiation contamination of the area (R1).

3.4. Instruments

The study of causal relationships between decision-making skills and preparedness to act in a CBRN setting employed Fs-QCA3.0 software and the Ragin and Davey's manual [25].

To educational experiment was conducted through the creation of a virtual reality simulator on the basis of a commercial HMD (Oculus Quest), which was aimed at the development of practical skills, such as technical knowledge, operational response, improvement of team structure and effective cooperation in dynamic scenarios. Student interaction with educational VR content was carried out using the Shinecon SC-G04BS virtual reality headset. The ECTS grading scale was used to evaluate the test results. The obtained data were analysed and processed using statistical methods and Table Edit software.

The participants of the expert group were surveyed using the Google Forms service at the beginning of the educational experiment. The survey used a psychometric Likert scale in 5 gradations: 1 – has absolutely no effect; 2 – no effect; 3 – partial effect; 4 – significant effect; 5 - maximum effect. Respondents' questionnaires were sorted by relevance, an independent sample T-test was performed, and the results showed no significant difference ($P > 0.047$). Harman's One Factor Test was used to check the systematic error of the common method. The variance of the first factor was 37.48% (less than 50%), confirming the absence of significant error of the general method in this study.

4. RESULTS

The servicemen's practical skills to respond to CBRN threats and the ability to make decisions are necessary for the implementation of effective targeted actions in the face of a treat of nuclear disasters. The results of the expert survey revealed a set of decision-making skills that influence the high, medium, and low levels of servicemen's preparedness to act CBRN emergencies. The results of the qualitative comparative analysis and the statistical analysis of the variables of the research conditions are presented in Tables **1**-**4**.

The Fs-QCA3.0 software was used to determine 5 configurations with a high and medium impact on the readiness of military personnel to act in case of radiation contamination of the territory with consistency of 0.902, 0.908, 0.905, 0.903 and 0.901, respectively. The total coverage was 0.531. The overall coverage of the model indicates that the five configurations explain about 53% of the possible cases. The analysis identified three changes with a low impact on servicemen's readiness to act in CBRN emergency. The total coverage was 0.493, which indicates that the three configurations explain about 49% of the possible cases. The results of the qualitative comparative analysis with fuzzy sets (fsQCA) are presented in Table **4**.

The S1 configuration shows that decision-making skills in CBRN incident detection or contamination, information management, and providing medical care to CBRN-affected people dominate the formation of the servicemen's readiness to act in CBRN emergency. At the same time, having decision-making skills in the field of individual and collective protection and in the field of dealing with CBRN threats have a secondary impact. The S2 configuration shows that the decision-making skills in the field of providing individual and collective protection and providing medical care to CBRN-affected people dominates the formation of the servicemen's readiness to act in CBRN emergency. Decision-making skills in the field of detection of an incident or contamination of CBRN and the field of working with CBRN threats have a partial effect, and decision-making skills in the field of information management has no effect on the preparedness to act. The S3 configuration shows that decision-making skills in the field of information management and in the field of providing health care to CBRN-affected people dominates the formation of the servicemen's preparedness to act in CBRN emergency. In the S4 configuration, the dominant conditions influencing readiness are the decision-making skills in the area of individual and collective protection and in the area of information management. In the S5 configuration, the dominant conditions of effect are the decision-making skills in the field of providing individual and collective protection and medical assistance to CBRN-affected people.

The H1, H2 and H3 configurations show that the lack of decision-making skills in the field of providing individual and collective protection and providing medical assistance to CBRN-affected people reduces the servicemen's preparedness to act in CBRN emergency. The configurations of low levels of preparedness to act in CBRN emergency show that the development of decision-making skills in CBRN settings must be approached comprehensively and holistically and equip the specialist with all the necessary knowledge and practical competencies necessary for effective work in the face of nuclear threats.

The study of causal relationships between decision-making skills of servicemen in CBRN emergency and their preparedness to act in case of radiation contamination made it possible to identify a set of skills, which affect the level of servicemen's preparedness to act in CBRN emergency. This gave grounds to build an effective learning strategy and structure the programme of the educational experimental course.

The educational experiment, which involved the students of the educational group took part, included a study of the possibilities of a simulation approach to learning using VR technologies for acquiring decision-making skills in the face of CBRN threats. Participation in the educational experiment gave students the opportunity to gain knowledge and build practical skills for responding to CBRN settings in an immersive educational environment. The training focused on the development of practical skills in 5 aspects of response:

1. Practical skills in detecting a CBRN incident or contamination, its identification and monitoring. In a virtual environment, students practiced their interaction skills with portable sensors, intelligent sensors, monitoring devices, electronic sources of environmental pollution data, etc. Students acquired the skills of interacting with radiation detection devices and learned to identify the most contaminated areas. Students learned to assess the scale and nature of the impact of gamma radiation after a nuclear incident under various variable conditions: environmental characteristics, nature of the incident, and weather conditions.

2. Practical skills in information management. The students developed the skills of team cooperation and coordination, collected, processed, and transferred CBRN intelligence data in the conditions of the simulation of collective interaction. They also learned to make decisions that would support the main requirements for CRMS data, namely: accuracy and error-free, low latency, energy efficiency, security, operational reliability. In a virtual environment, students developed the skills of effective communication and cooperation with the government and emergency response services.

3. Practical skills to ensure individual and collective protection, as well as protection of equipment and materials. In the virtual space, students worked on the skills of implementing the first line of protection against the effects of gamma radiation, namely preventing or limiting direct exposure. They developed skills of the effective use of protective clothing and equipment. Students also worked out structural protection scenarios using protective materials with a high atomic number, buildings and structures that reduce the penetration of gamma radiation. The students developed the skills of organizing and conducting a collective evacuation from radiation sites and from areas with a high level of radiation in realistic conditions created with the help of the VR system.

4. Practical skills in providing medical care to CBRN-affected people. Students acquired practical skills in emergency decontamination, chelation therapy, gastrointestinal decontamination, and wound decontamination. The students acquired skills in a safe environment to implement CBRN mitigation countermeasures and to respond effectively in the event of a nuclear incident.

5. Practical skills in dealing with CRMS threats, development of preliminary measures, prevention of threats, control of spread and decontamination. Under simulated threat conditions, students had the opportunity to acquire CBRN threat planning and forecasting skills and develop strategic threat prevention programmes.

The aspect of the accuracy of decision-making in case of CBRN incidents became the main reference point for the development of test situational tasks for students of the study group. The testing was conducted at the end of the three-month course. The results of testing the EG and the CG students are presented in Table **5**.

Table 5: Results of Students' Knowledge Assessment after the Educational Experiment

Evaluation index	Score (points)		Deviation
	CG	EG	
Accuracy of decision-making in the field of detection of CBRN incident or contamination	78	85	7
Accuracy of decision-making in the field of information management	72	90	18
Accuracy of decision-making in the field of providing individual and collective protection	74	91	17
Accuracy of decision-making in the field of health care for CBRN-affected people	81	95	14
Accuracy of decision-making in the field of countering CBRN threats	82	92	10
Average value	77.4	90.6	13.2

The results of the experiment show a significant advantage of simulation training in virtual reality compared to traditional training with the help of educational video content. The students who learned with the help of VR demonstrated higher decision-making accuracy in various areas related to CBRN threats. These results give grounds to recommend the integration of simulation training in VR into educational programmes to increase the effectiveness of training specialists for CBRN threats.

5. DISCUSSION

The educational experiment demonstrated the effectiveness of using VR tools for the development of decision-making skills in the context of CBRN threats. The VR simulator enabled the EG students to immerse themselves in realistic scenarios of events and practice collective and individual decision-making skills by performing tasks in a simulated virtual environment. The training course was aimed at developing practical skills in responding to and countering gamma radiation threats resulting from a nuclear power plant explosion or nuclear bombing. The students trained in operational response, tactical and strategic decision-making, management decisions, as well as cooperation and coordination skills. In a VR environment, they developed technological knowledge and learned how to interact with CBRN threat detection tools. In paper [10], was concluded that simulation as a didactic method is a viable form of CBRN training, especially one aimed at introducing modern equipment. CRMS mission-specific training requires the development of a series of simulation-based activities that help students acquire safe behaviour skills while testing their performance. The results of a study involving thirty-nine fast close combat fighters from the British Air Force showed that different forms of simulation can provide fundamentally different learning environments – creating different levels of complexity, immersion.

The results of a study analysing the VR effectiveness in military training in the Korean army showed that VR-based training is more effective than video-based training due to factors such as interest, realism, immersion, and understanding [26]. The results of a study involving students at an infantry school in France showed that training with a VR simulation that immerses them in an immersive simulated situation facilitates the activation of the cognitive levers needed to master the procedure. This allows students who learn using a VR simulator to learn a practical skill with fewer iterations than students who learn using 2D software [27]. The results of our study also demonstrated the effectiveness of simulation training with VR tools for developing decision-making skills in simulated nuclear threat environments. The EG students who studied in the virtual environment showed a 13.2 points better result (90.6 points) in the accuracy of decision-making than the CG students (77.4 points) who studied with the use of educational video content.

The results of a study [28], which involved police officers from Belgium, Amsterdam, Romania, Sweden, and Germany, showed that the main advantage of using virtual training environments for CBRN response training is the possibility of implementing personalized training. VR offers the ability to automatically record all relevant indicators to assess the effectiveness of learning in each session, calculate expected future results and thus make learning progress measurable and predictable. The respondents identified another strength of learning in a virtual environment, namely increased frequency of training, which leads to more repetitions, enabling students to better learn and retain their knowledge. Our study employed the method of qualitative comparative analysis of fuzzy sets (fsQCA), which allowed us to identify a set of skills, which affect the level of servicemen's preparedness to act in CBRN emergency. This made it possible to develop an effective learning strategy and structure the programme of the educational experimental course. According to the authors, the combination of this method with innovative teaching methods allows to simulate an effective learning environment and implement targeted training programmes for the development of the necessary skills of emergency response to CBRN threats.

There is no doubt that physical fitness is the foundation of effective professional training for military, police, and CBRN emergency responders [29]. The training system should include physical training, self-defence tactics, and personal safety [30]. It is necessary to develop the specialists' clear awareness and importance of their powers, an understanding of the degree of responsibility assigned to them in the performance of their function [31]. The results of an educational experiment conducted by the Chernobyl Exclusion Zone showed that first responders can benefit from a realistic environment for training in real-world conditions while assuming a reasonably acceptable risk of exposure to ionizing radiation. Providing a safety plan for such exercises and its proper implementation, including the use of appropriate personal protective equipment and adherence to strict safety rules, guarantees an acceptable level of safety for all participants [7]. The results of our educational experiment showed that VR-based training is effective for developing decision-making skills in the face of CBRN threats. According to the authors, promising directions for further research are the search for opportunities to combine training programmes for nuclear risk response skills in real conditions and simulation training programmes in virtual space.

6. CONCLUSIONS

The development of servicemen's practical decision-making skills in the face of chemical, biological, radiological and nuclear (CBRN) hazards is a priority task of military training, especially in view of the military conflict in Ukraine. The study of causal relationships between the decision-making skills of servicemen in CBRM emergency and their preparedness to act in cases of radiation contamination of the territory identified 5 configurations with a high and medium impact on the readiness of servicemen to act in conditions of radiation contamination of the area and 3 - with a low one. The analysis identified a set of decision-making skills that affect the high, medium, and low levels of servicemen's preparedness to act in CBRN emergency. This made it possible to form priority areas of training aimed at comprehensive preparation for responding to CBRN threats.

The results of the educational experiment showed that VR-based simulation training was more effective than training using monitor video content. In general, the EG students demonstrated a 13.2 points better result (90.6 points) in decision-making accuracy than the CG students (77.4 points).

The result of the study confirms the effectiveness of creating simulation scenarios for learning how to respond to CBRN threats and shows their positive impact on the accuracy of decision-making in the context of CRMS threats. The obtained results can be used to improve the training of servicemen to act in cases of CBRN incidents. The method of qualitative comparative analysis of fuzzy sets (fsQCA) presented in the study can be used to develop effective personalized training strategies aimed at increasing the servicemen's readiness to act in the face of nuclear threats.

Research prospects are the development of methods of interactive personalized training of servicemen using virtual, augmented and mixed reality technologies, aimed at acquiring practical skills for responding to nuclear threats.

RESEARCH LIMITATIONS

The main limitation of this study is the small size of the sample and its narrow geographical characteristics. The study involved 34 teachers and 98 students of higher educational institutions. Furthermore, the study is reduced to the generalization of the conditions for conducting fsQCA analysis.

APPENDIX A

Table A.1: Expert Group Participants

Number	Institute/Faculty	Higher education institution
3	Institute of State Military Administration	National University of Defence of Ukraine
2	Military Doctors Training Faculty	Ukrainian Military Medical Academy

4	Faculty of Combat Application of Control and Communication Systems	Kruty Heroes Military Institute of Telecommunications and Information Technology
5	Faculty of Information Technologies	
6	Military Law Institute	Yaroslav Mudryi National Law University
4	Operational and Rescue Forces Faculty	National University of Civil Protection of Ukraine
3	Fire Safety Faculty	
7	Technogenic and Environmental Safety Faculty	
Total: 34 people		

Table A.2: Participants of the Study Group

Number	Major	Institute/Faculty	Higher education institution
11	Ecology (Environmental Safety)	Faculty of Technogenic and Environmental Safety	National University of Civil Defence of Ukraine
14	Environmental Protection Technologies (Engineering and Environmental safety)		
12	Chemical Technology and Engineering	Faculty of Operational and Rescue Forces	
17	Firefighting and Emergency Rescue Operations		
14	Civil security	Civil Protection Faculty	
17	Engineering support of mining, pyrotechnic and explosive works		
13	Extreme and crisis psychology	Socio-Psychological Faculty	
Total: 98 people			

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