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The role of simulation training for engineering troops to work in the field

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ABSTRACT

The aim of the article is to empirically measure the possibilities of using virtual simulations to train engineering troops to work in the field. A set of test methods was used for diagnostics, as well as observation and formative experiment. Similar dynamics of the levels of activity and cognitive components of readiness for work in the field were revealed in the experimental group (EG) and control group (CG). In both groups, the significance indicators of the Wilcoxon test are at p=0.01 (T=211; T=198; T=201; T=209). Simulation training proved to be quite effective in stabilizing risk-taking and anxiety among engineering troops, which is confirmed by Wilcoxon tests at p=0.01 (T=178; T=169). No significant differences were found in the dynamics of the teamwork skills (T=196; T=181). Indicators of the ability to adhere to the norms of professional ethics did not change in both groups (T=299; T=309). Therefore, the positive psychological role of virtual simulators for the readiness to work in the field can be stated. The obtained results determine the foundation for optimizing the strategies and tactics of military training for work in the field, taking into account the capabilities of the modern information environment.

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1. INTRODUCTION

The servicemen live their lives and carry out their professional activity in difficult conditions, which involve constant household discomfort, frequent changes of deployment, and distancing from the family [1]. In wartime, these factors are complemented by an increased level danger to human life and health. In this context, the issue of high-quality training of military specialists is becoming relevant, which should give the maximum positive result with the minimization of negative reactions to military occupations and the development of professional skills [2], [3]. Military training involves a wide range of activities aimed at mastering various skills, in particular, learning how to use specialized equipment, physical training, and mastering combat tactics [4]. The basis of high-quality training of servicemen is purposeful practice of skills through field training [5]. In this context, the concept of modelling and simulation is an effective tool for optimizing the professional development of the military since World War II [6], [7]. In the current conditions, the role of information technologies, in particular, multimedia simulators [8] and artificial intelligence (AI) [9], is growing significantly.

The advantage of these tools in the training of military personnel is the simulation of circumstances, which stimulates the most “real” emotions and cognitive processes [10]. Researchers are gradually becoming more interested in studying the use of simulation training for training specialists of various branches of research [11], [12]. At the same time, there are almost no attempts to study this problem in the context of training engineering troops. It is worth noting that the engineering troops play an exceptional role in the creation of the country’s complex defence infrastructure, so the training of specialists in this field requires special attention [13], [14]. In the period of a full-scale war, the creation of qualified personnel potential of military units is especially relevant, as it ensures the high-quality performance of combat tasks.

The aim of the article is to empirically find out the possibilities of using virtual simulations for training engineering troops to work in the field. Research objectives: i) determine the principles and conditions of using simulation training for servicemen; ii) find out indicators of readiness of military engineering troops to work in the field; and iii) experimentally check the effectiveness of using simulation training for engineering troops to work in the field.

2. LITERATURE REVIEW

The effectiveness of professional training of servicemen determines the overall operational combat capability of the armed forces [15] and depends on the proper physiological and psychological justification of this process [16]. It is important to create optimal stress conditions during military training that will increase readiness to carry out combat mission and not cause deterioration of the structure of professional abilities [17]. It is promising to study the peculiarities of the collective training of servicemen, which involves shared experience and better assimilation of relevant professional experience [18]. The influence of information warfare [19] should be taken into account in the training of servicemen, which can destabilize the mental state and deform the professional development of personnel. It is also appropriate to focus on the formation of a legal culture of the behaviour of servicemen during the hostilities [20]. The main strategic goal of such military training should include orientation to NATO standards and the use of modern technologies in the training process, in particular AI [14].

The planning of virtual simulations in professional education should provide for the correspondence of the created didactic environment to the current reality [21]. The matter is about the so-called validity of the virtual construct, which can be determined by the effectiveness of the activities of experienced servicemen and novices [22]. The use of augmented reality in the military field has proven itself positively in training aircraft pilots, practicing weapons skills, and improving combat tactics [23]. In the organization of influence, it is advisable to take into account not only the realism of the computer simulation, but also the nature of user interaction with the informational learning environment [24]. The introduction of simulators based on virtual reality is an effective tool for military training, provided they are integrated with field training [25]. At the same time, Yamamoto and Altun [26] claim that military training using simulators does not differ in quality from field training.

The main advantages of using virtual reality in military training are the possibility of repeating the training task, the absence of risk to the physical health of the military, cost savings [27]. Unambiguously positive features of the use of this technology in army training are effective and vivid visualization of combat conditions, which stimulates the development of terrain orientation skills and the speed of assessing combat conditions in coordination with various units [28]. Simulators have a positive effect on the intellectual performance of military personnel, namely, concentration of attention, perceptual qualities, working memory, and systems of cognitive processing of information in combat conditions [29]. Augmented reality plays a significant role in training the teamwork of the unit to perform missions in an operational environment [30]. It is worth noting that the financial costs of purchasing high-quality virtual reality systems are one of the factors preventing their widespread implementation in military practice [31]. This is especially true for poor countries. There is scientific evidence proving a reduction in the cognitive load of military personnel during training in a 3D environment compared to 2D [28]. At the same time, the accuracy and reaction time of the skill does not differ significantly in both types of simulation. Subjective visualization during training exercises differs from traditional training [32].

Therefore, the theoretical analysis of the problem confirms a high number of studies on the use of virtual reality for military simulation training in the academic literature. At the same time, the use of such technologies in the training of engineering troops has not been studied. Furthermore, the issue of using virtual simulations to prepare the military for activities in the field remains insufficiently studied.

3. METHOD

The research was implemented as a formative experiment. The structure corresponds to the main methodological and scientific principles. The study included the following stages:

- Research planning-determination of time, human, and economic resources, which involves the development of a sequence of research actions. The samples consisted of servicemen of engineering troops. The administrative and organizational issues of the study with the leadership of the military units were resolved. Great importance was attached to an adequate selection of data collection tools and means of experimental influence. The opinion of experts the military, teachers, and psychologists were taken into account. The persons responsible for implementing experimental and diagnostic procedures have also been identified. The following criteria for the readiness of a specialist of engineering troops of demining units to work in the field are identified: knowledge in the relevant field; professional skills and abilities; experiencing anxiety; risk-taking; teamwork skills; ability to comply with the norms of professional ethics. Significant attention was focused on manifestations of the emotional sphere, which reflects reactions to the complex conditions of the combat situation. At this stage, the research hypothesis is determined: the use of simulation training based on virtual reality technologies is an effective tool for training specialists of demining units of engineering troops to work in the field.
- The stage of collecting research dataconducting diagnostics of the readiness of engineering troops to work in the field. Collecting empirical data included two stages: before and after the experiment. In turn, the experiment procedure involved using simulation training technologies involving virtual reality. All actions for the collection of empirical data were carried out under the direct training of military personnel in military units.
- Stage of data interpretation and concluding the results of the experiment. The data were summarized in accordance with the explanation of the degree of influence of simulation training in virtual reality on the training of engineering troops to work in the field. Data interpretation was based on a structural approach.

3.1. Instruments

A set of substantiated research methods was used to study the components of the readiness of engineering troops to work in the field. The mining test was used to determine the level of knowledge in the professional field. The test was created by servicemen and teachers of military higher education institutions (HEIs), taking into account the content and specifics of training programmes with a view to the content of the professional standard of combat engineer training. Observations were used to determine the level of development of professional skills and abilities of engineering troops. The accuracy of actions carrying out a combat mission, compliance with the established algorithm of carrying out a combat mission, speed of carrying out the assigned mission were chosen as the observation criteria. Observation was also used to determine the level of the teamwork skills and the ability to adhere to the norms of professional ethics. The technique of diagnosing risk taking was used to assess the behaviour of an individual in an extreme military situation [33]. Taylor's method of studying anxiety [34] was used to diagnose indicators of stability of the emotional sphere.

3.2. Sample

The study involved the servicemen of demining units of engineering troops who were trained in military units of Ukraine. The studied groups consisted of personnel who were just beginning to undergo training and had no previous experience of service in demining units. The samples were formed in close cooperation with the leaders of the military unit. The dynamics of competence levels was determined depending on the organization of the training process. Two samples were formed, namely experimental group (EG) exposed to formative influence and control group (CG) without formative influence. The quantitative composition of each sample is 40 people. The total number of subjects is 80 servicemen. Only men were involved in the study.

An important aspect of research is to find out the similarity of the CG and EG before starting the experiment. According to qualitative characteristics, both groups are as identical as possible, but their statistical similarity should have been determined. The Pearson Fitting Criterion were calculated for this purpose, Table 1. The obtained empirical indicators for all parameters are less than the significance level of $p=0.05$, which indicates the maximum consistency of the primary numerical data for both samples.

3.3. Data collection

The diagnostic methods were applied during direct work with the research participants. The experimental exposure was based on the formative strategy for two months, which corresponds to the basic preliminary training period in the demining units. The method of the formative experiment provided the use of simulation training involving virtual reality in the training of servicemen of demining units as an independent variable. Strata.22 software was used for experimental exposure. The dependent variable of the experiment is the readiness of servicemen of demining units for carrying out missions in the field. Experimental exposure took place during the course of training in the combat unit. The realization of the independent variable involved the regular introduction of simulation training using virtual reality to the training sessions. The situations of searching for explosive objects, disarming explosive objects, and the behaviour of a combat engineer in a combat situation were simulated. Such classes were preparatory to practicing skills with real projectiles and substances. At the same time, no such simulation training was provided in the CG, but only practical training in the field. The time and programme of classes in both groups did not differ. The first diagnostics was carried out before the formative influence, and the second diagnostics after the completion of the training course.

Table 1. The indicators of the pearson fitting criterion

Studied parameters	Pearson fitting criterion
Professional knowledge	34.245
Professional skills and abilities	23.562
Risk taking	27.895
Anxiety	31.509
Teamwork skills	28.983
Ability to comply with the norms of professional ethics	22.543

3.4. Data analysis

The data analysis is aimed at comparing the results of control and experimental samples. For this purpose, the percentages are presented in the form of charts. The indicators for each studied component are divided into three levels: high, medium, and low. The Kolmogorov-Smirnov test was used to check whether the experimental data corresponded to a normal distribution. The Wilcoxon T-test was used to detect statistically significant differences. SPSS software was used for data analysis.

4. RESULTS AND DISCUSSION

Diagnostic results are presented in the charts below. For clarity, the percentage distribution of the levels of each studied component is graphically presented. The data are presented by diagnostic stages in the CG and EG. The obtained results are further analysed.

The results of changes in professional knowledge during the experiment are presented in Figure 1. The primary diagnostics demonstrated the absolute dominance of low indicators of the component (more than 80% of respondents). This situation is understandable, as the study involved military recruits who had just started a training course in the relevant field. Only a few subjects from the sample demonstrated medium indicators of knowledge in the engineering field. Re-diagnostics showed a change in indicators towards a significant increase in the number of servicemen with high indicators of professional knowledge. An increase in the high level of the component up to 60% was found in both groups. No significant differences were found between the two groups. The positive trends in the growth of knowledge in the field of demining is associated with the intensive course of theoretical and practical training of the military because of the wartime conditions. The subjects demonstrate the best results on the explosives and explosive items. Less positive trends in the component are recorded for reconnaissance and demining means section. The subjects were the worst oriented before and after the formative influence in the legal regulation of combat engineer' activities.

The change in professional abilities and skills in the studied groups is shown in Figure 2. The primary diagnostics in both groups demonstrate the dominance of low indicators of the activity component of combat engineers' readiness to carry out combat missions (92.5-95%of respondents). Repeated diagnostics shows pronounced positive dynamics in both groups. There were no significant differences between the results of the servicemen's diagnostic examination. There is a significant increase in the average indicators of the professional skills and abilities of combat engineers (80-85% of respondents). After the end of the experiment, low and high indicators were recorded in a small number of subjects. The obtained results do not give grounds to talk about the positive impact of simulated virtual training, compared to traditional methods of military training. The skills of using individual means of protection were developed most effectively, which was confirmed by the results of observations. Favourable dynamics of the ability to destroy structures by explosives have also been recorded. Developing of the skills of neutralization and destruction of explosive items turned out to be problematic. This process is accompanied by increased negative emotional experiences. The educational training was insufficiently favourable for the development of the ability to handle artillery shells and bombs, which is due to the lack of previous military experience of the subjects.

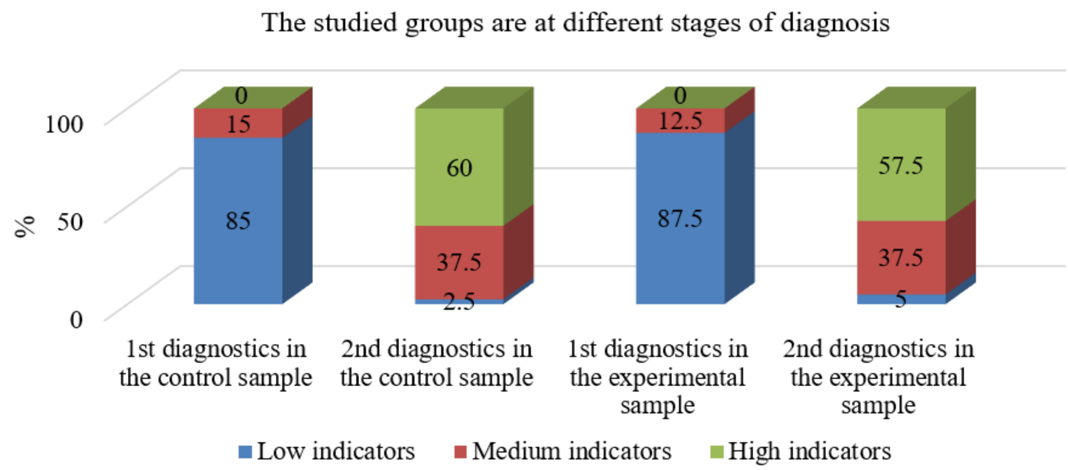

Figure 1. The dynamics of changes in professional knowledge of combat engineers in the course of military training

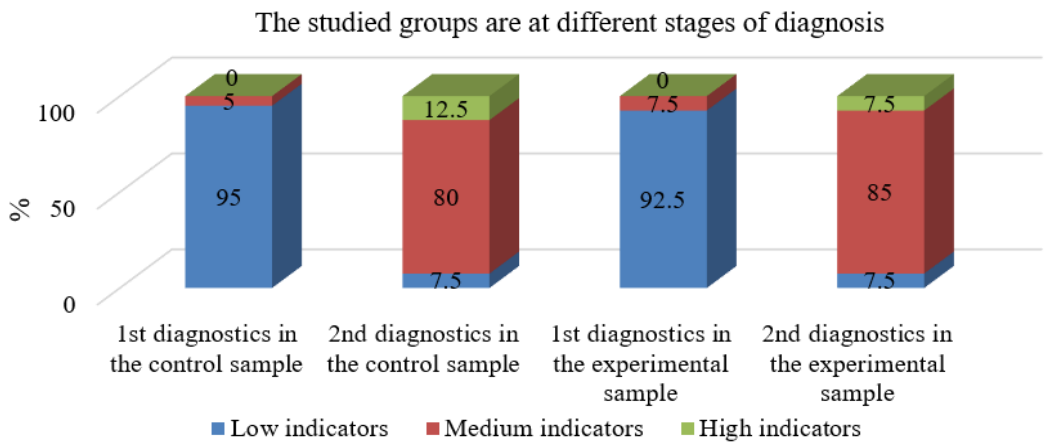

Figure 2. The dynamics of changes in professional skills of combat engineer in the course of military training

The dynamics of risk taking in the studied groups is presented in Figure 3. Before the start of the experiment, low indicators of risk-taking among military personnel were recorded (57.5% of respondents). This tendency is associated with the stability of civilian life attitudes and the adaptation of the individual to the conditions of military service. Medium indicators of this emotional component were found in a third of the subjects. No significant changes were found in the CG after the completion of the military training course and changes in levels were recorded only in two people. A significant increase in the medium indicators of risk taking was found in the EG-by 45%. The medium level of this component is the most optimal for carrying out combat missions of combat engineers, as it characterizes the balance between the self-preservation instinct and courage. The high indicators of the component in the EG changed insignificantly. The obtained results testify to the effectiveness of the use of simulation training in achieving the optimal level of risk-taking in demining units. Reckless, impulsive actions were observed during the demining algorithm at the beginning of training. These trends were especially manifested in work on virtual simulators. A gradual improvement in the ability to think through one's own actions during demining and analyse the current operational situation is recorded during military training. We associate these trends with the stabilization of the servicemen's risk propensity.

Figure 4 shows changes in the anxiety of the studied combat engineers during the experiment. At the beginning of the experiment, 52.5% of the studied soldiers had high levels of anxiety. Medium indicators of this component of readiness were diagnosed in 40%. After the formative experiment was completed, the number of people with high levels of anxiety decreased by 10% in the CG. In the EG, the number of surveyed servicemen with high anxiety levels decreased by 45%. The percentage of respondents with a medium level of the component increased by 37.5%. Therefore, simulation training in virtual reality is an effective means of overcoming the anxiety of military demining units of engineering troops. Observation of the respondents gives reason to claim that the highest levels of anxiety were recorded at the beginning of training and acquiring the professional skills of a combat engineer. Such reactions were observed even in the situation of simulated training in virtual reality. Anxiety is more pronounced in situations of practical classes, compared to theoretical ones. This is related to the awareness of the situation of danger to life and health during demining operations.

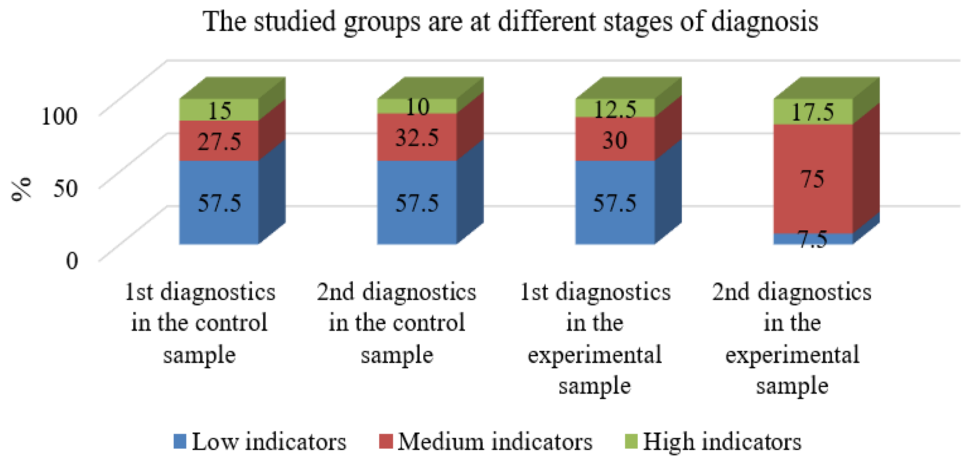

Figure 3. The dynamics of changes in combat engineers' risk taking in the course of military training

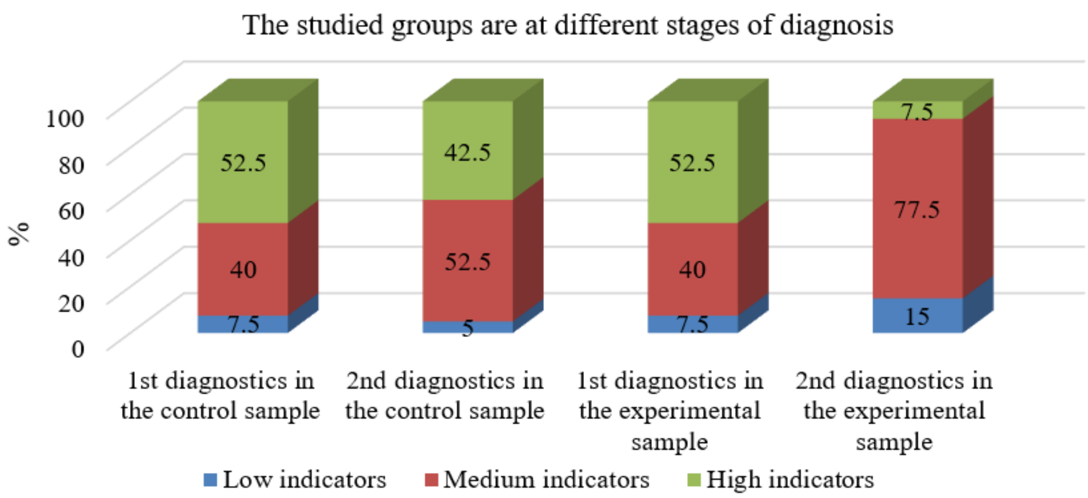

Figure 4. The dynamics of changes in the anxiety of combat engineers in the course of military training

Changes in the teamwork skills during the experiment are presented in Figure 5. The primary diagnostics showed the dominance of low component levels in both groups (57.5% of the subjects). Traditional approaches to educational training have demonstrated better effectiveness in the dynamics of this component compared to the use of simulators. In the CG, increased average indicators of the teamwork skills was recorded in 42.5% of the subjects, while in the EG recorded in 27.5%. This situation is explained by a greater share of collective training in the CG. At the same time, the simulation training of combat engineers was more focused on individual work.

Changes in the ability to comply with professional and ethical norms during the experiment are presented in Figure 6. The primary one shows the predominance of high and medium values of the component (at the level of 90%). This is explained by the previous socialization influence and norms for servicemen. Low performance components are presented minimally. Therefore, military training did not significantly change this component, which is associated with its persistent dependence on personal structures.

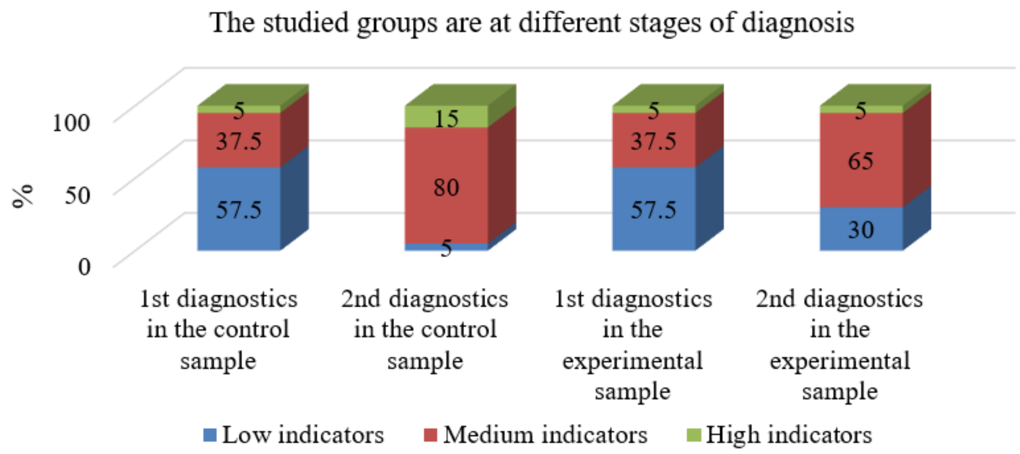

Figure 5. The dynamics of changes in the teamwork skills of combat engineers in the course of military training

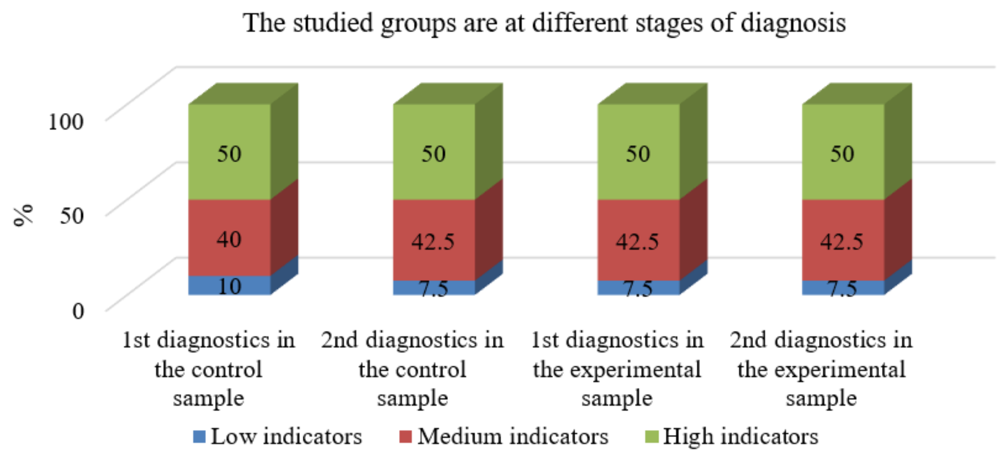

Figure 6. The dynamics of changes in the ability to adhere to professional and ethical norms in the course of military training

Statistical series were checked for conformity to a normal distribution using the Kolmogorov-Smirnov test to substantiate further statistical procedures. The results are shown in Table 2. We can see that the asymptotic significance for the parameters professional knowledge, professional skills and abilities, teamwork skills and ability to comply with Professional Ethics is less than 0.05 in all cases. For the components Risk Taking and Anxiety, the coefficient of the Kolmogorov-Smirnov test is higher than 0.05 only for the statistical series of repeated diagnoses in the EG. The obtained data demonstrate the appropriateness of using the Wilcoxon T-test in further data processing.

The results of the study of statistical differences between the indicators of primary and secondary diagnostics are presented in Table 3. Significant differences ($p=0.01$) were recorded in both samples for professional knowledge, professional skills and teamwork skills. At the same time, in the CG, no statistically significant dynamics were found in risk-taking and anxiety. No significant changes were found in both groups for ability to comply with the norms of professional ethics. In the EG, these components show differences at the level of $p=0.01$.

As a result of the formative experiment, the research hypothesis was confirmed that the use of simulation training based on virtual reality is an effective tool for training servicemen of demining units to work in the field. We have established that the implementation of these technologies does not provide an additional effect in military training compared to traditional training. Professional skills are developed less effectively during specialized training compared to knowledge. This is explained by the fact that the development of specific military skills is associated with additional stress. Moreover, the most acute emotional reaction for explosions in the field was recorded.

Table 2. Indicators of the Kolmogorov–Smirnov criterion for the studied parameters

Parameters	Asymptotic significance			
	CG 1	CG2	EG1	EG2
Professional knowledge	0.034	0.029	0.041	0.030
Professional skills and abilities	0.044	0.339	0.047	0.492
Risk taking	0.023	0.026	0.033	0.562
Anxiety	0.004	0.019	0.023	0.228
Teamwork skills	0.032	0.422	0.030	0.034
Ability to comply with the norms of professional ethics	0.087	0.072	0.063	0.069

Table 3. Indicators of the Wilcoxon T-test in the CG and EG

Components of readiness of combat engineers to perform tasks in the field	Wilcoxon t-test	
	CG	EG
Professional knowledge	211**	201**
Professional skills and abilities	198**	209**
Risk taking	303	178**
Anxiety	297	169**
Teamwork skills	196**	181**
Ability to comply with the norms of professional ethics	299	309

Note: **=significance of differences at the p=0.01 level.

At the same time, simulation training proved to be quite effective in stabilizing risk-taking and anxiety among servicemen. The traditional educational approach has not demonstrated such effectiveness. In general, we support the opinion about the effectiveness of using virtual simulators in a combination with field training of the servicemen [25]. In this way, the psychological basis for the assimilation of specialized knowledge and skills is provided. At the same time, simulation training will make it possible to design training in accordance with the physiological indicators of a particular serviceman, which will increase the overall effectiveness of training [16]. There is an essential opinion regarding the provision of an optimal stress background during the performance of educational tasks [17]. In particular, our study found that sudden or excessively loud explosion sounds in a virtual simulation disorientated servicemen just beginning their professional training. Therefore, we consider it appropriate to take into account the realism of the simulation and adjust it depending on the specific emotional state of the servicemen during training [21]. At the same time, we cannot confirm the conclusions about reducing the cognitive load of the military in the context of virtual simulation [28].

On the contrary, quite strong intellectual tension in the military was recorded during the training process. Differences in the social conditions of military training can explain the difference between the obtained results. In particular, it should be considered that the actual research took place in the conditions of an ongoing war. It is interesting to compare the dynamics of teamwork ability with the results of similar studies [30]. In particular, we concluded that the traditional form of training with a group form of work is more effective.

Further research of the chosen issue may be finding ways to improve the training of servicemen of demining units using simulation training. In particular, a clear system of counteracting the effects of information warfare and information psychological operations during the educational process should be developed [19]. Increasing orientation in legal issues of wartime will strengthen the ideological component of military training [20]. The effectiveness of simulation training will increase if this effect is differentiated by computer literacy skills [22]. It is appropriate to combine the capabilities of 2D 3D in the process of conducting training military exercises [28] and involve AI [9]. The implementation of such approaches in the training of military demining units of engineering troops will allow testing new training strategies [13].

5. CONCLUSION

A full-scale war urges the issue of finding innovative approaches to personnel training. Modern realities determine the relevance of the influence of information technologies on all social processes, in particular, military ones. The research hypothesis was confirmed as a result of the formative experiment. It was established that the implementation of simulation training in the practice of training specialists of demining units does not give an additional effect compared to traditional training. Similar dynamics of the levels of activity and cognitive components of readiness for activity in the field were revealed in the EG and CG. No significant differences were found in the dynamics of the teamwork skills.

The indicators of the ability to comply with the norms of professional ethics did not change in both groups. Simulation training proved to be quite effective in stabilizing the risk-taking and anxiety of engineer troops. So, the positive psychological role of virtual simulators for the making servicemen ready to work in the field can be stated. The obtained results determine the foundation for optimizing the strategies and tactics of military training for work in the field, taking into account the capabilities of the modern information environment. The conducted research has certain wartime-related limitations; therefore, it is advisable to determine the research prospects. In particular, it is appropriate to experimentally determine the specifics and effectiveness of the use of simulation training for personnel of various types of troops.

The results of the study could be more complete with the involvement of servicemen of other units of engineering troops, not only combat engineers. At the same time, the research was significantly limited by the conditions of wartime and the need to prepare for the conditions of war as quickly as possible. Also, it is expedient to include a larger number of military personnel for more representative results, but we worked with a maximum allowable contingent within the current social situation.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

DATA AVAILABILITY

Due to confidentiality and privacy agreements with the participants, the datasets during the current study are not accessible to the general public. However, upon reasonable request, the corresponding author may provide derived data that supports the study’s findings. Data access requests will be evaluated in accordance with participant privacy and ethical approval. The data that support the findings of this study are available from the corresponding author, [OB], upon reasonable request.

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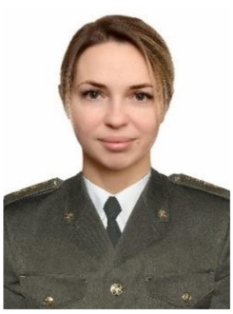

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