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A Preliminary Assessment of the Effectiveness of Training Using a Virtual Reality Simulator of the Anti-aircraft Missile Launcher

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Abstract

Training an anti-aircraft soldier is expensive, complicated, and time-consuming. As a result, many countries, weighing the cost-effectiveness, opt to introduce solutions aimed at minimizing this trend. One of them is incorporating modern training devices such as simulators and trainers into the training. However, to make this happen, it is worth analyzing the effectiveness of training with their use by comparing it to that conducted in a traditional way. With this in mind, the purpose of this article is to present the results of research on the effectiveness of using a Virtual Reality (VR) simulator developed at the Military University of Technology in teaching the construction and basic activities of combat work in the area of conducting a selected check of the functioning of the SA6 Gainful missile launcher system. The theoretical foundation for the empirical research was provided by a method of analyzing literary content. By using the method of comparison and generalization, knowledge was obtained about the general construction and use of training devices in the training of the anti-aircraft defense forces of the Polish Armed Forces, and the features of the VR simulator were described. As regards the empirical methods, a study was conducted using a research sample which was conducted using a parallel triangulation strategy scheme involving the simultaneous use of quantitative and qualitative methods. The synthesis served in formulating the final conclusions and in determining the relationships between theoretical and empirical studies. The results obtained in this way can provide valuable information about the effectiveness of using training devices in training anti-aircraft defense forces and serve as a basis for further work on their development and application.

Keywords: Air Defense, simulator, training, training device, trainer, Virtual Reality

1. Introduction

The Air Defense Forces have constituted an essential combat capability of the Polish Armed Forces (PAF) for many years. An analysis of the experience of the war in Ukraine shows that diverse aerial adversaries pose probably the greatest threat to the Air Defense Forces. This situation is undoubtedly influenced by changing technology. Highly advanced and modern air threats require more and more from the anti-aircraft defense systems. This issue is also inseparably connected with proper preparation, and consequently, the appropriate training of anti-aircraft soldiers.

Over the years, a certain persisting trend can be noticed in the PAF. It pertains to intensifying training using all kinds of modern educational tools, such as training devices. Nowadays, these are technically advanced machines that allow saving both time and money. Currently, the most commonly used tools are simulators and trainers (Bogusz, 2022). The Air Defense Forces are also not lagging behind in this area and have a significant amount of this type of equipment.

The Air Defense Forces are also not lagging behind in this area and have a significant amount of this type of equipment.

Considering the above, it seems reasonable to clarify these concepts, as some flexibility in their interpretation means that they are often used interchangeably in many studies. Thus, a simulator is a training device that imitates the operation of specific combat equipment; it serves to reproduce real situations in artificial conditions, making the training situation similar to a combat one (Leksykon wiedzy wojskowej, 1979).

More generally, this term has been defined as “a device that enables the operator to reproduce or represent under test conditions phenomena likely to occur in actual performance” (Merriam-Webster, n.d.).

On the other hand, a trainer is described as a training device for the individual and team training of soldiers of various types of armed forces, troops, and services in the use and operation of combat equipment, machines, devices, and instruments. A trainer replaces combat equipment in certain training activities. Mechanisms and training devices corresponding to original models allow training in real conditions (e.g., aiming training, vehicle operation) (Leksykon wiedzy wojskowej, 1979).

From the terms mentioned above, it can be concluded that both simulators and trainers are training devices intended, among other things, for training soldiers. Thanks to changes in technology, they are increasingly replacing real equipment in training, bringing tangible financial benefits.

Although the origins of simulation techniques used in the Polish Army date back to the 1990s, growing interest in battlefield simulation technology in the PAF could be observed from the beginning of the 21st century. Therefore, over time, they have become significant tools used daily in soldier training. One of the first anti-aircraft defense simulators to be introduced using Virtual Reality (VR) technology was described in the article (Milewski et al., 2012).

The current rapid pace of development and widespread access to VR technology create excellent conditions for its broader use in the process of training soldiers, especially in the initial stage of acquiring knowledge about the construction and principles of military technology operation.

The aim of this work is to present the results of research on the effectiveness of using a VR simulator developed at the Military University of Technology (MUT) for teaching the construction and basic activities of combat work in the field of conducting a selected check of the functioning of the SA6 Gainful missile launcher system.

2. An overview of training devices used in the training of the Anti-Aircraft Defense Forces of the Polish Armed Forces

It is commonly known that anti-aircraft defense systems are classified into the Surface-to-Air Missile (SAM) system, Antiaircraft Guns, and combined Antiaircraft Artillery-Missile (AAM) systems (Andruszkiewicz & Pająk, 2008). However, only some of these have their counterparts among training devices dedicated to the air defense forces in the various PAF branches.

a. Training devices used in the Land Forces

The Land Forces’ Anti-Aircraft Defense Troops are a vital element in executing the tasks of shielding armored and mechanized components. Hence, it is important for commanders at every level, whether in regiments, squadrons, or anti-aircraft batteries, to have access to the appropriate training instruments dedicated to the weaponry they possess. Selected examples are described below:

- OSA Antiaircraft System Simulator: designed to train the SA-8 GECKO system (9K33 OSA) crews to develop habits enabling effective combating of aerial targets in various battlefield scenarios generated in virtual space (WZU, n.d.a). This is achieved using a simulation technique of the optoelectronic head GOE01. With such a solution, generating a virtual image (day, night) and implementing a laser rangefinder is possible. The device also features imagery of simulated radar spectra characteristic of circular observation and missile guidance. There is the possibility of working on pre-prepared scenarios with multiple Transporter-Erector-Launcher-And-Radar (TELAR) crews simultaneously and editing them according to the training needs and character.9F632 Trainer of 9A33BM3 TELAR (modified version 9F632.M1): the 9F632.M1 device enables simultaneous training

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of six SA-8 Gecko TELAR crews and helps trainees develop habits and behaviors in detection, recognition, and target selection for destruction, interception, and automatic tracking, including those using disturbances. An advantage of the trainer is the ability to control the level of training or conduct group target shooting (Kosowski, 2012). A digital air situation simulator allows, among other things, the generation of air situations, management of flight parameters of aerial objects, electronic warfare means, and monitoring of the trained crew. It also implemented the ability to generate a target based on an external real radar source (WZU, n.d.b).

- TR-23 Trainer: A mobile training device based on the ZUR-23-2KG AAM system. It consists of an operator station and an instructor station connected by a wireless network. The operator uses a monitor in the sight's place, displaying a simulated image of the tactical situation. The trainer enables exercises in detecting, recognizing, and tracking aerial, ground, and naval targets during both day and night, in different atmospheric conditions, and allows simultaneous training of four gun crews (Berezowska, 2017).
- UST-1 GROM Training Device: Intended for learning to shoot with a MAN Portable Air Defense system (MANPADs). It allows conducting exercises and evaluating the mastery of basic skills of using a combat set (such as targeting, tracking, and switch handling). The operator at one of the four training stations performs the same actions as in combat shooting. In addition to physical control, the instructor supervising the course of training has a computer at his disposal, by means of which he assesses the correctness of executing a firing task (Kołacz, 2009).

b. Training devices used in Air Force

The fundamental armament of the Air Force's Anti-Aircraft Defense Troops belongs to the 3rd Air Defense Missile Brigade, the SA-3 GOA SAM system (ver. NEWA SC). Hence, there are several training devices dedicated to it.

- NEWA SC Simulator: This procedural-diagnostic simulator for the SA-3 Goa SAM system of the CPT (Cockpit Procedures Trainer) type features replicated rocket system operator consoles along with most indicators (Sienicki et al., 2015). Its visualization system is based on VR technology solutions and Augmented Reality (AR), allowing for the virtual creation of objects, surroundings, and events. Consequently, the crew is able to perform functions such as operation control or combat training. Key elements of the simulator include the command and guidance cabin equipment, an autonomous set for creating multimedia presentations with augmented reality elements, a large-format graphic presentation system, and an instructor's station (Karczmarz et al., 2016).
- TR-I NEWA SC Trainer: This is the TR-I instructor device set that enables the creation of scenarios for aerial and missile raids, and subsequently, based on this, conducting combat work training for short and medium-range missile squadron personnel (Kiński, 2013). The device consists of a portable computer, simulating devices, a power block, modems, and converters located in a crate. An important element of the trainer is the OCENA application used to analyse collected data during simulated fire control and assist the instructor in assessing the fire team's training level. An advantage of the device is its modularity, i.e., the ability to connect (cooperate) with a radar station or another missile system.

c. Training devices used in the Navy

Training anti-aircraft defense troops for the needs of the Navy is conducted using the following devices:

- TR-MANPADs GROM Trainer: This is designed for training shooters of MANPADs Grom. The device enables learning the operation of the system's mechanisms, detecting, tracking, and recognizing aerial objects, virtually firing at them, and then checking the effects. The trainer consists of an instructor's station, equipped with a computer designed for battlefield simulation and 3D image generation. Based on VBS2 software (Virtual Battle Space 2), the visualisation system provides a realistic depiction of the surroundings, considering terrain, weather, atmospheric conditions, and sound effects. Furthermore, it includes a broad database of aerial vehicles (mobile/static) and training scenarios intended for trained operators. The instructor selects missions from a list or creates them from scratch and can freely configure them and select parameters (Bielawski et al., 2013). The instructor's station is wirelessly connected to the operator's station.
- TR-23-2MR Trainer: This is based on the naval version of the ZUR-23-2M AAM system. The device is intended to train the operator-gunner on the structure and practical use in simulated maritime conditions (AREX, 2011). The trainer allows for carrying out both artillery and missile fire tasks, depending on the characteristics, against aerial, surface, and coastal targets under various sea states (i.e., within 0 to 3 degrees on the Beaufort scale). The operator-gunner's station is mounted on a non-combat version of the ZU-23-2MR AAM system and placed on a special, movable platform. An LCD monitor has been placed where the tachometric sight was, displaying the tactical situation of the battlefield and surroundings to the trainee. The instructor has access to a wide range of exercise scenarios, depicted using a three-dimensional visualization system, supported by a sound system.

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3. Characteristics of the VR Simulator for the SA-6 Gainful Missile Launcher System

The simulator consists of three main levels that allow the trainees to first familiarize themselves with the control method in the VR system. Afterwards, they are able to acquire theoretical and practical skills related to carrying out the procedure for checking the execution of the assigned target coordinates by the launcher's control systems in a static state. The programmatically implemented automatic recording system enables tracking and correcting errors and allows trainees to interrupt training at any time. At each stage of training, the participant can make use of the so-called virtual instructor who provides audiovisual hints.

The software was developed using the Blueprint Visual Scripting environment, contained in the Unreal Engine 5.1.1 graphics engine. To run the simulator, specific hardware and software requirements must be met. The hardware requirements include the possession of the Oculus Rift S system, while the software requirements pertain to the Windows 10 x64 operating system and Microsoft Visual C++ 2015-2022 Redistributable (x86). In the VR simulator, a smooth way of moving using the controller has been implemented, enabling work in office space. Additionally, the trainee has the opportunity to create an individual profile to track training progress and adjust the height of the trainees' character according to their needs.

4. Preliminary assumptions and research description

The aim of the conducted research was to test the null hypothesis (H0):

"There is no significant difference in training effects between the group trained traditionally
and the group trained using the VR simulator."

A research sample of 12 cadets studying at the MUT was chosen to conduct a study on the effectiveness of the developed VR simulator in the training process for operating the SA-6 Gainful missile launcher. The study participants volunteered, and all those who were willing and met the inclusion criterion, namely, military studies in mechatronics, were included in the sample. There was no need to apply exclusion criteria.

Participants were paired and randomly assigned to one of two training groups (i.e., the test or the control group). Participants were paired based on their previous academic achievements. The underlying rationale was pairing participants with similar progress in learning and abilities that would enable them to achieve similar training.

It was assumed that the research would be conducted using a parallel triangulation strategy scheme, using quantitative and qualitative methods simultaneously. The results of the study conducted with this scheme are well justified and credibly presented by Croswell (Creswell et al., 2007). The simultaneous collection of quantitative and qualitative data took place at the research site and was faster than in the case of sequential studies.

The adopted research scheme is presented in Fig. 1. It includes information about the interventions, measurements, and time intervals between subsequent activities.

Pairing increased the power of the obtained statistical test at the expense of increased uncertainty in the final outcome, as the withdrawal of one participant from a given group could necessitate the exclusion of their counterpart's results in the other group.

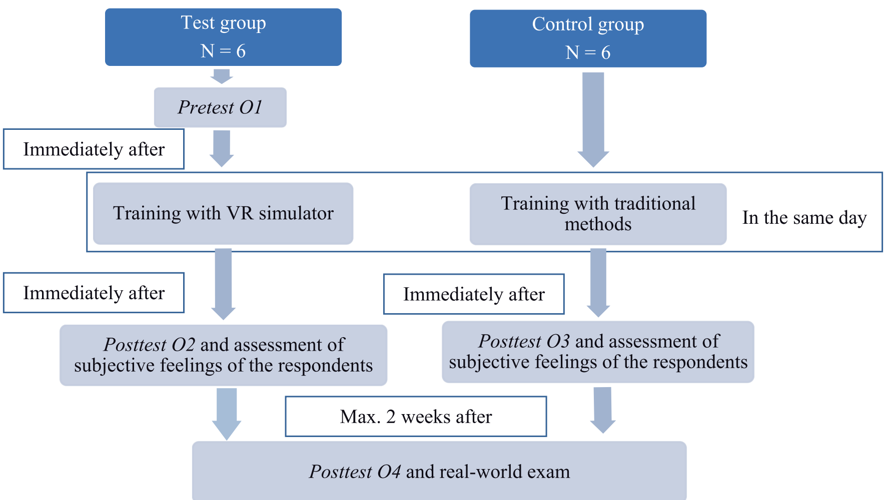

Fig. 1. Task-time scheme of the research

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Conducting training for the control group by employing the traditional method was necessary to compare the effectiveness of training the test group using the VR simulator. For this purpose, a 90-minute practical session was planned using the SA-6 Gainful missile launcher system and instructional boards. The classes were conducted at three teaching points according to the organizational scheme presented in Fig. 2.

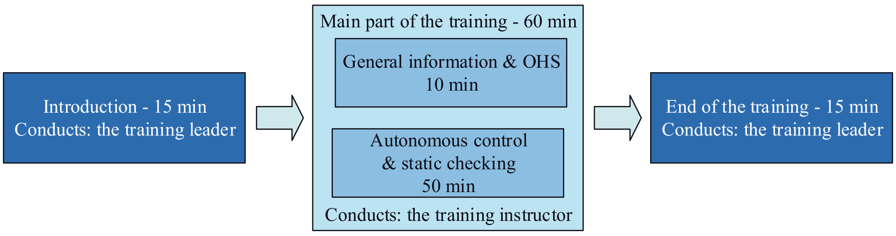

Fig. 2. Organizational diagram of the control group classes using the traditional method

Prior to the training, participants were introduced to general information about using the missile launcher and detailed safety rules while working with it. The training was conducted using demonstrative and lecture methods, and the time allocated for its completion was 15 minutes. The second teaching point aims to train the participants in conducting independent checks using their own systems and to verify the execution of coordinates in a static state. The training was carried out through practical sessions, with a duration of 60 minutes. After completing the traditional training, the participants completed a survey (Posttest O3) evaluating the form of training and the skills they acquired.

Before starting the training with the VR simulator, the participants filled out a personal questionnaire (Pretest O1) to assess their psychophysical state. At the beginning of the training, the instructor calibrated and prepared the VR simulator according to each participant's individual preferences, while informing them about safety conditions and the possibility of interrupting the training at any time. During the training, the instructor answered the participants' questions and addressed any issues related to the training or the simulator's operation. Soldiers could pause and resume training at any time and repeat any number of times; however, they should not exceed the set 90 minutes of training time (it was recommended to complete at least one set of exercises with the VR simulator during this time). Throughout the training, the instructor noted down his observations on participants' progress. At the end of the training, the instructor summarized the achieved training results in the final teaching point. After the sessions, the participants filled out a well-being assessment questionnaire (Posttest O2) and a survey evaluating the training using the VR simulator (Posttest O3).

The last element of the conducted research was an exam during which the level of knowledge and practical skills of all trainees in both groups were verified. The exam was conducted by an independent examiner and consisted of two parts. In the first part, the theoretical knowledge of the trainees regarding the selected procedure for verifying the launcher's operation was tested. Examinees were assessed on their understanding of individual procedural actions, the structure of related assemblies and devices, and the control signals emitted from the monitored components. The exam was conducted individually for each participant, and the examiner was unaware of whether a particular person was trained using the VR simulator or the traditional method. During the exam, data was collected through full observation, paying attention to the trained individuals' confidence and decisiveness in performing tasks. After the exam, an open, unstructured interview was conducted with the examiner to understand his opinion regarding the trainees' level of preparation.

The study on the effectiveness of the developed VR simulator in the training process for the SA-6 Gainful missile launcher took place from April 3 to 6, 2023, in three locations: the MUT technical park (traditional training method), the soldier's room (training using the VR simulator), and the temporary dislocation of the combat group (real-world exam using combat equipment).

The exam was divided into two parts (Fig. 3). The theoretical part involved testing the examinees' knowledge of:

1. when the verification is performed – 4 pts;
2. the purpose of performing the procedure – 2 pts;
3. devices and launcher assemblies involved during the procedure – 5 pts;
4. signals coming out from individual components – 4 pts.

The practical part involved testing the skills of working on the launcher. The following areas were assessed:

1. preparing the launcher – 15 pts;
2. executing the main part of the procedure – 27 pts;
3. returning the launcher to its initial position – 3 pts.

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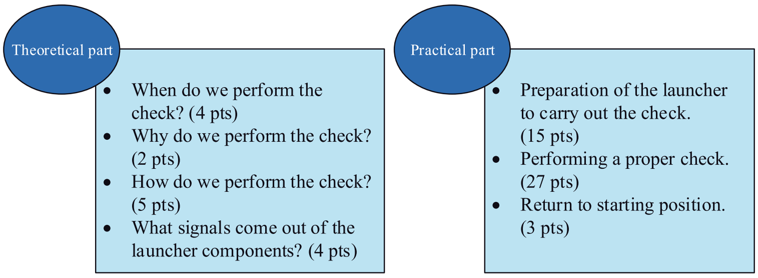

Fig. 3. Exam evaluation criteria – Posttest O4

The time taken to perform tasks was not evaluated. The exam was tailored to the nature of the chosen procedure, allowing the cadets to correct their mistakes and draw conclusions.

5. Results

Testing the null hypothesis H0 required a clear separation and analysis of data obtained quantitatively and qualitatively. Subsequently, both data sets were analyzed independently of each other. The part containing quantitative data was intentionally conducted first to set a backdrop against which, in the next stage, qualitative data was quantified.

Quantifying the results of qualitative research allowed for a comparison of the analysis outcomes for the purpose of cross-validation.

a. Quantitative

The exam results of individual participants are presented in Table 1, and the obtained scores for each person are shown in Figure 4.

Table 1. The exam results of the test and control groups

Participant code	Theory [pts]	Launcher preparation [pts]	Main part of exam [pts]	Return to initial position [pts]	Total score [pts]	Percentage
			Test group			
A1	14.0	15.0	27.0	4.0	60.0	98.4%
B1	15.0	13.0	26.0	4.0	58.0	95.1%
C1	9.0	15.0	27.0	4.0	55.0	90.2%
D1	6.0	15.0	17.0	4.0	42.0	68.9%
E1	7.5	14.0	26.0	4.0	51.5	84.4%
F1	13.0	10.0	22.0	4.0	49.0	80.3%
Mean	10.75	13.67	24.17	4.0	52.58	86.2%
Std. Dev.	3.4126	1.7951	3.6248	0	6.0029	9.84%
			Control group			
A2	11.0	15.0	27.0	4.0	57.0	93.4%
B2	9.0	11.5	17.0	4.0	41.5	68.0%
C2	4.5	11.5	22.0	4.0	42.0	68.9%
D2	5.0	14.5	27.0	4.0	50.5	82.8%
E2	15.0	14.5	27.0	4.0	60.5	99.2%
F2	8.0	13.0	17.0	4.0	42.0	68.9%
Mean	8.75	13.33	22.83	4.0	48.92	80.2%
Std. Dev.	3.5795	1.4337	4.4876	0	7.6671	12.57%

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The data have been visualized in a chart (Figure 5), which displays the arithmetic mean of the exam scores obtained by both groups, with the standard deviation value highlighted.

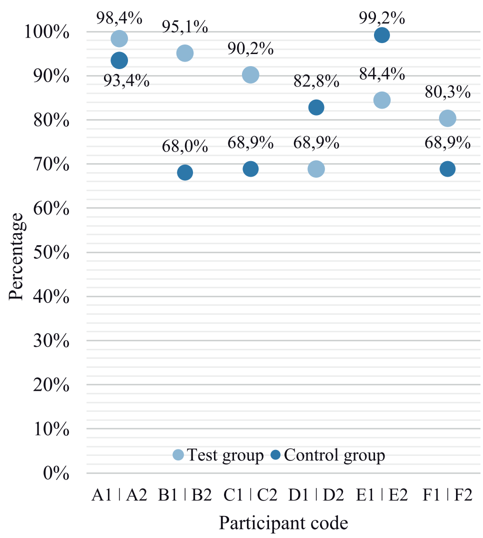

Fig. 4. Percentage results of the exam of participants in both groups (test and control)Source: Office of the Secretary of Defense, 2018.

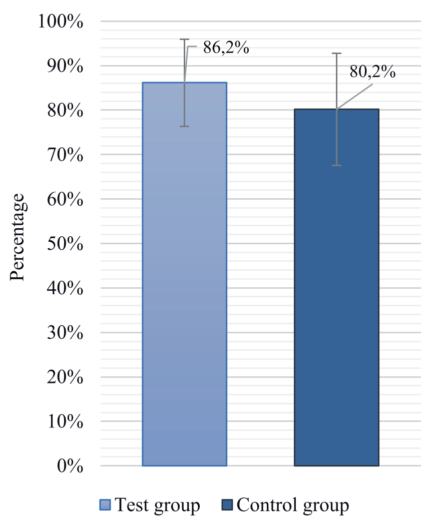

Fig 5. Mean values of the exam scores for the test and control group

The exam results broken down into their components were depicted in a chart to gain more detailed insight (Figure 6). The smallest difference was observed during the phase of returning to the initial state. Every study participant correctly executed this. The most noticeable difference was observed during the assessment of the participant's theoretical knowledge. At this stage, those trained using the VR simulator scored 13.4% higher than those trained using traditional methods.

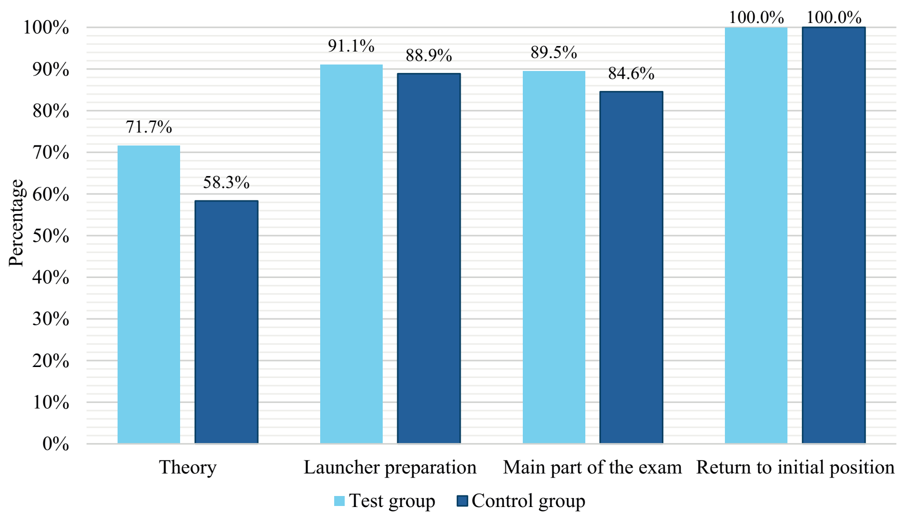

Fig. 6. Percentage scores (mean value) of the exam components

A two-sided *T*-Student test was employed to verify the H0 hypothesis. Typically, during the design of a study, an a priori calculation of the desired sample size (N) is made using statistical significance (α), the power of the statistical test (β), and the effect size (ES). In the present study, with a sample size N = 12 and drawing on the results of a work (Lipsey, 2009) concerning research of a similar practical nature, it was decided to adopt a condition of $\alpha = \beta$ and an effect size value expressed on Cohen's *d* scale (Cohen, 1977) as an initial approximation at ES = 0.8.

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For the aforementioned statistical assumptions, the critical value *t*, and the values of α and β for the paired *T*-Student test were calculated using the G*Power 3.1.9.4 software (Faul et al., 2007), according to a simplified schema presented in Figure 7.

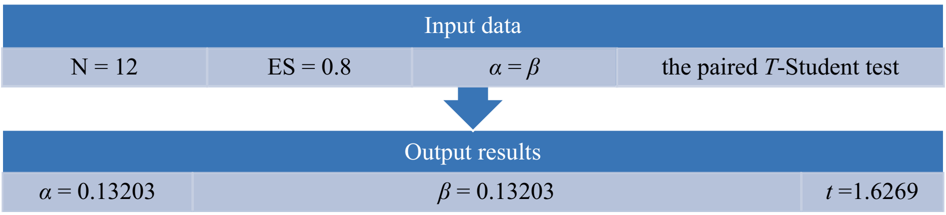

Fig. 7. A simplified diagram of the input data and the output results of the statistical analysis obtained using the G*Power 3.1.9.4 software

For this purpose, the averaged total results of the trained groups and their standard deviations were used. The empirical value of the test statistic at the level $t_{emp} = 0.84$ was calculated from the following relationship:

$$t_{emp} = \frac{\bar{x}_D - \mu_0}{\hat{s}} \cdot \sqrt{N} \tag{1}$$

where:
μ_0 – statistical population (assumed $\mu_0 = 0$);
$\bar{x}_D$ – arithmetic mean of differences between individual pairs of participants;
$\hat{s}$ – standard deviation between individual pairs of participants;
N – number of pairs of participants.

The test probability at the level of $p = 0.439$ was calculated from the following relationship:

$$p = 2 \cdot f_{t,d}\left(-\left|t_{emp}\right|\right), \tag{2}$$

where:
$f_{t,d}$ – distribution function of the *T*-Student test depending on *d*-DOF (degrees of freedom):

$$d = \frac{\bar{x}_D}{\hat{s}} \tag{3}$$

d – effect size value expressed on Cohen's *d* scale.

The above results indicate that there is insufficient evidence to reject the H0 hypothesis for the adopted effect size value ES = 0.8.

Using the exam results, ES = 0.32 was recalculated using formula (3) and employing Cohen's d scale. The obtained result suggests that there are slight differences in favor of training using the VR simulator.

In addition to Posttest O4, the trainees' subjective feelings were also considered on a six-point scale (0-5). The arithmetic means of these ratings are presented in the chart (Fig. 8) divided into the following evaluation categories:

- *instructor's qualifications* (substantive knowledge and ability to convey information);
- *positive aspects of the training* (appeal and time for practicing the topic);
- *negative aspects of the training* (too much theory compared to practice, noticeable boredom);
- *ease of the procedure.*

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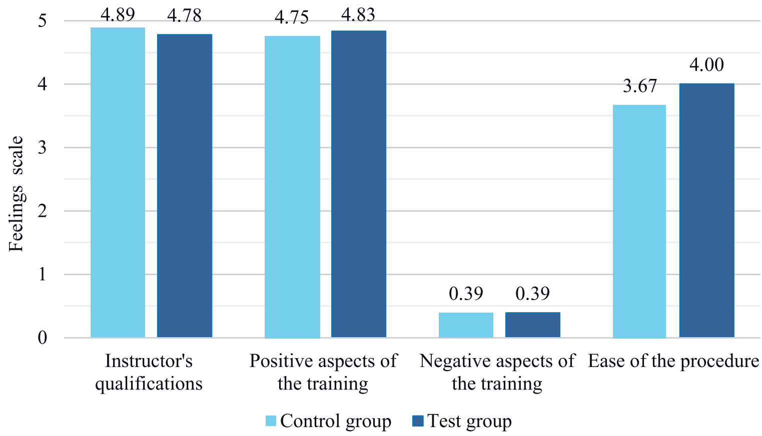

Fig. 8. Distribution of participants' ratings in particular training categories

The presented research results indicate that both types of training (i.e., the one using the VR simulator and the traditional method) were conducted at a high level in terms of methodology and content. The greatest discrepancy concerned the ease of the procedure. Cadets using traditional teaching techniques were more inclined to state that the procedure could be described as not overly complicated.

b. Qualitative

In the course of the examination, a full observation of the trainees was conducted, noting general impressions regarding the skill in carrying out the procedure and the mistakes made. After the study was completed, an interview was conducted with the examiner. The data thus obtained for individual cadets were combined and presented in Table 2.

Table 2. A set of qualitative assessments

Test group		Control group	
Participant code	**Assessment (X ; Y)**	**Participant code**	**Assessment (X ; Y)**
A1	(P ; P)	A2	(P ; P)
B1	(P ; P)	B2	(N ; N)
C1	(P ; N)	C2	(N ; N)
D1	(N ; N)	D2	(P ; N)
E1	(N ; N)	E2	(P ; P)
F1	(N ; P)	F2	(N ; N)

P – positive; N – negative; X – based on participants observations; Y – based on the examiner's interview.

A slight difference was observed concerning theoretical knowledge in favor of training using the simulator. The number of cadets who flawlessly executed the procedure is the same for both training groups. The data obtained in two ways are consistent with each other, with one exception. The result of participant B2 was considered to his disadvantage. This was due to a prior decision on the higher hierarchy of data obtained through an interview with the examiner.

The data from Table 2 were quantified based on the number of cadets in both groups who fully performed and understood the topic and are presented in the chart (Fig. 9).

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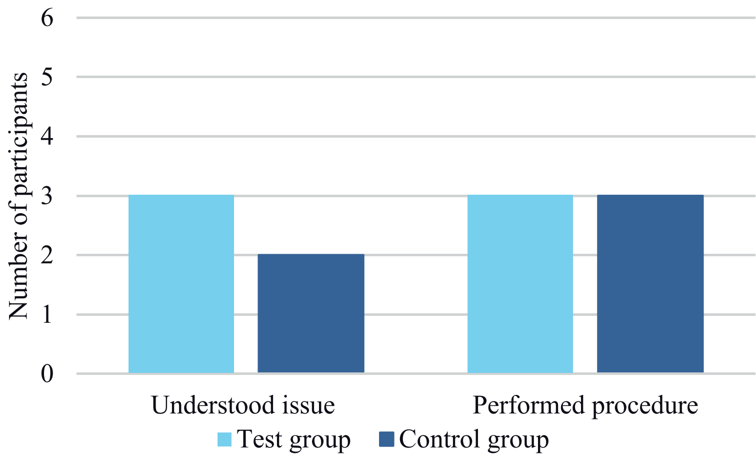

Fig. 9. Distribution of participants in groups who fully understood and performed the issue

Based on the obtained results, it was determined that there is insufficient evidence to reject the null hypothesis H0. The observable improvement in understanding the procedure among cadets using the VR simulator cannot be considered significant (ES = 0.8). Rejecting the hypothesis based on a small effect size would be a mistake due to the too small sample size.

6. Conclusions

The proper training of an operator (system) for anti-aircraft equipment is expensive and labor-intensive. Therefore, an increasing number of countries are seeking solutions aimed at rapidly preparing soldiers for battlefield operations in as short a time as possible. One of the methods to address this issue is the introduction of modern training devices into the training process.

Given Poland's costly purchase of modern air and anti-aircraft defense systems as part of the WISŁA, NAREW, and PILICA programs, supporting the training and preparation process for their operation seems indispensable. However, their training must also be appropriately organized to effectively implement the preparation process of a specialist – an operator – anti-aircraft gunner.

The results of preliminary studies unequivocally indicated the high effectiveness of using the developed VR simulator for teaching the structure and basic combat operations related to conducting a chosen check of the functioning of missile launchers of the SA-6 GAINFUL system. This is confirmed by the fact that quantitative analyses are consistent with data obtained qualitatively. Moreover, both research methods indicate minor existing differences in knowledge level between cadets from both groups, favoring cadets trained using the VR simulator. Nevertheless, drawing a clear conclusion that both training methods are equally effective based on the aforementioned preliminary research results would be erroneous. The experiment should be replicated and cross-validated at a different time, under the influence of other factors. Therefore, more extensive research on a larger sample and with a suitably selected training scope should be conducted.

The high realism achieved by replicating the characteristics of combat equipment and the modern battlefield means that, in many respects, training devices can successfully replace weapons without losing the effectiveness of the training. In this case, the development of appropriate exercise programs or the inclusion of tasks using them in training programs will be crucial. Furthermore, conducting preliminary training for soldiers on a simulator or trainer before operating real equipment is worth considering. In the future, linking the training devices of the anti-aircraft defense forces with identical tools used for the virtual training of aircraft pilots (Dobrzyński & Zalewski, 2011) undoubtedly merits consideration. This would allow the creation of a simulation center for the needs of the anti-aircraft defense forces of the Republic of Poland, Additionally, anti-aircraft gunners could undergo cyclic training in cooperation with other entities by using various means of combat and improving the tactics of operation in response to virtual aerial threats simulated by trained combat pilots.

Declaration of interest
The authors declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

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