Experimental Evaluation of Camouflage Effectiveness Against Ground-Based Surveillance

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Abstract: Camouflaging mortar firing positions represents a critical force protection measure in modern conflicts, aiming to prevent enemy observation and subsequent destruction. The objective of this pilot study is to evaluate the effectiveness of various camouflage techniques in concealing mortars, ammunition assets, and support equipment from detection by selected ground-based reconnaissance means. The experimental phase employed a range of artillery reconnaissance sensors, optical devices, and unaided visual observation. The observed targets including mortar firing positions of various calibres and decoy positions were camouflaged using different methods and levels of concealment, and deployed in terrain with varying vegetation density and spatial characteristics. The detected differences in target visibility highlight the strengths and limitations of individual observation methods depending on target characteristics and environmental conditions. The findings of this pilot study offer practical recommendations for the effective camouflage of mortar units in current operational environments.

1 INTRODUCTION

The current battlespace of multi-domain operations, characterized inter alia by high-intensity sensor surveillance and widespread deployment of unmanned systems, imposes extraordinary demands on unit protection—particularly in terms of camouflage. Mortar units are especially vulnerable to detection by enemy artillery reconnaissance assets, notably during emplacement in firing positions and while conducting fire missions (Sedláček et al., 2023; Havlík et al. 2022). This vulnerability underscores the necessity for rational planning and allocation of defence resources under conditions of increasing risk (Šlouf et al., 2023).

Each artillery discharge generates a visual, acoustic, and thermal signature. The ongoing war in Ukraine has demonstrated that the integration of unmanned aerial vehicles (UAVs), thermal imaging devices, and multi-sensor platforms with an efficient kill chain can significantly increase the probability of early target acquisition and rapid destruction of firing positions (Khoma, 2023; Ali et al., 2023). As a result, camouflage has become one of the critical components of artillery force protection.

With the ongoing advancement of technologies, sophisticated command and control systems (C2/C4ISR) are increasingly coming to the forefront. These systems enable the real-time integration of sensor data and significantly accelerate the decision-making cycle (Amphenol Aerospace, 2023). Within this framework, artificial intelligence (AI) is beginning to assert its role, facilitating automated object detection, behaviour prediction, and enhancing the probability of identifying concealed targets through machine learning methods (Beals, 2023). Traditional camouflage techniques, when not adapted to address these emerging threats, can be easily

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defeated in combination with image recognition algorithms (Ali et al., 2023). Therefore, future development of camouflage systems must be closely aligned with advancements in AI, computer vision, and predictive analytics, in order to maintain operational effectiveness even in environments characterized by intense digital reconnaissance (Hughes, 2024). In future implementations, integrating artificial intelligence and computer vision into the decision-making process may significantly enhance the reliability of camouflage assessment and deployment, particularly by mitigating human error and enabling automated terrain analysis from UAV imagery.

Effective protection and concealment of artillery units require a multi-faceted approach (Ivan et al., 2022). Currently employed methods include natural camouflage, technical camouflage systems (e.g., camouflage nets), the deployment of decoy firing positions, and the implementation of "shoot and scoot" tactics. The overarching objective of these measures is to reduce the likelihood of unit detection by enemy reconnaissance assets.

Minimization of visual reflections, suppression of thermal and electromagnetic signatures, and environmental adaptation of deployed units also play a critical role in modern camouflage practices (Khoma, 2023; Zhang et al., 2021). In contemporary armed forces, camouflage often relies on traditional methods (e.g., disruptive patterns, natural materials) while simultaneously undergoing modernization. For example, the introduction of the MAD21 camouflage pattern is intended to enhance concealment in both natural and urban environments (CZ Defence, 2022).

Parallel to these operational measures, scientific methodologies have emerged to quantify camouflage effectiveness. Notable research directions include the evaluation of visual similarity between objects and their surroundings based on human perception (Li et al., 2022), the application of network analysis and clustering algorithms (Kim, Yang & Kwon, 2021), and the development of adaptive materials aimed at reducing thermal signatures (Su & Zhao, 2023).

Advances in detection capabilities have been driven by the evolution of deep neural networks utilizing datasets such as MCAM (Hwang & Ma, 2024), and model architectures like MilDETR (Li et al., 2024), CAMOUFLAGE-Net (Karthiga & Asuntha, 2025), and YOLOv5/YOLOv7, which have proven effective when deployed on UAV platforms (Zeng et al., 2024).

Further studies have examined the impact of visualization techniques on human decision-making, particularly the risk of situational awareness degradation due to excessive target highlighting. When digital interfaces overemphasize objects through colour, size, or motion observers may focus disproportionately on marked elements and overlook other critical aspects of the tactical environment (Gardony et al., 2022).

Some lines of research draw inspiration from biological mechanisms, such as mimicry, bionics, and adaptive behaviour, which are being applied in the development of next-generation camouflage systems (Matthews et al., 2024). However, most of these studies are conducted under laboratory or simulated conditions. There remains a lack of experimentally grounded research that evaluates the effectiveness of camouflage techniques in real terrain settings and against a broad spectrum of modern sensors conditions that closely approximate the operational battlefield.

This pilot study aims to address this research gap. The primary objective is to assess the effectiveness of selected camouflage and deception methods applied to mortar units under conditions resembling current combat environments. The study seeks to contribute to a more comprehensive understanding of protection strategies for artillery firing positions. At its core, this research is based on a field experiment.

Based on the outlined context, the study was designed to address the following research questions (RQ):

RQ1: What is the difference in detection rates of camouflaged positions depending on the applied camouflage method?

RQ2: Which type of sensor is most successful in detecting realistically camouflaged targets?

RQ3: Can decoy positions be effectively used as part of a tactical approach to reduce detection probability?

Drawing from existing knowledge, the working hypothesis posits that natural camouflage will be more effective than decoy positions in open terrain when observed through optical means, while camouflage nets are expected to perform less effectively in the infrared spectrum. To test this assumption, a null hypothesis (H_0) was formulated, stating that there is no statistically significant difference in detectability among the different types of camouflage.

2 EXPERIMENTAL FRAMEWORKS

This research responds to the current operational need to verify the effectiveness of camouflage methods under conditions that reflect the realities of today's sensor-saturated battlefield. Given the widespread deployment of UAVs, thermal imaging, and multisensory platforms that enable precise target acquisition, it is essential to test whether traditional or modernized camouflage techniques can effectively reduce the likelihood of detection.

The experiment was designed as an initial pilot phase of a broader research effort, aimed at comparing the detectability of objects camouflaged using various techniques within a selected operational environment. In addition to measuring direct detection rates, the study also assessed a range of supplementary variables relevant to the operational applicability of sensor systems:

Level of Confidence in Target Detection – a subjective observer rating on a scale from 1 to 5 indicating the degree of certainty regarding the correctness of target identification,

Subjective Evaluation of the Observation System – including clarity of the image, ease of use, and the observer's perceived ability to distinguish between targets,

Type of Detection Error – categorized as Type I errors (false positives) or Type II errors (missed detections of actual targets),

Observer Selection Behaviour – the order in which participants chose specific sensor platforms for target detection tasks.

The results of this pilot study are intended to inform the design of a larger-scale experiment focused on validating camouflage effectiveness across different seasonal conditions and with an expanded participant base. This step is essential for generating repeatable data applicable to the protection of mortar units operating in contemporary combat environments.

3 MATERIALS AND METHODS

The primary objective of this study was to experimentally verify the effectiveness of various forms of camouflage for mortar firing positions under realistic field conditions and to analyse their resistance to detection by ground-based sensor systems. A secondary objective was to record variations in the detection rates of individual targets, including the occurrence of Type I errors (false positives) and Type II errors (missed detections), as well as to assess the observers' subjective confidence in their detections when employing different types of camouflage.

3.1 Materials

The parameters for the field experiment were derived from actual equipment and structures commonly associated with the operations of mortar units. Emphasis was placed on creating a diverse set of observed targets and camouflage configurations, reflecting both standardized and improvised concealment techniques typically employed during real-world deployments.

3.1.1 Variables

The **independent variable** was the type of camouflage applied to the target, categorized as natural camouflage, camouflage netting, no camouflage, and decoy position.

The **dependent variables** were: the detection rate (expressed as a percentage), and the time required to detect the target.

The **controlled variables** included: the distance between the target and the observer, the time of day, ambient light conditions, and the type of observation post employed.

3.1.2 Sample Selection

The observation tasks were conducted by students and members of the Czech Armed Forces (CAF) representing various military specializations. A total of 23 students from the Faculty of Military Leadership participated in the experiment. A purposive sampling strategy was employed to obtain a representative sample of users familiar with real military equipment and operational procedures. The participants had no prior knowledge of the location or type of camouflaged and decoy objects.

3.1.3 Environment and Conditions

The experiment was conducted on a designated training range featuring natural vegetation with gradual transition into light forest terrain. Observations were carried out at varying distances ranging from 150 to 400 meters, allowing the simulation of dynamic battlefield conditions.

3.2 Methods

Data were recorded using standardized observation forms, which included:

- Fields for the type of detected object, the observation system employed;
- The observer's confidence level (rated on a 1–5 scale);

- The type of detection error (Type I – false positive; Type II – omission of an actual target);
- The estimated distance to the target.

The forms were collected after each observation block, digitized, and subsequently anonymized for statistical processing.

For the statistical analysis, a combination of descriptive and inferential statistical methods was employed. Descriptive statistics included the calculation of arithmetic means, standard deviations, and variances for the observed variables.

To test for statistical associations, a chi-square test was used to evaluate the relationship between the type of camouflage and the detection rate. Furthermore, a one-way analysis of variance (ANOVA) was conducted to compare the effectiveness of the different observation systems employed in the experiment.

3.2.1 Observed Objects and Camouflage Techniques

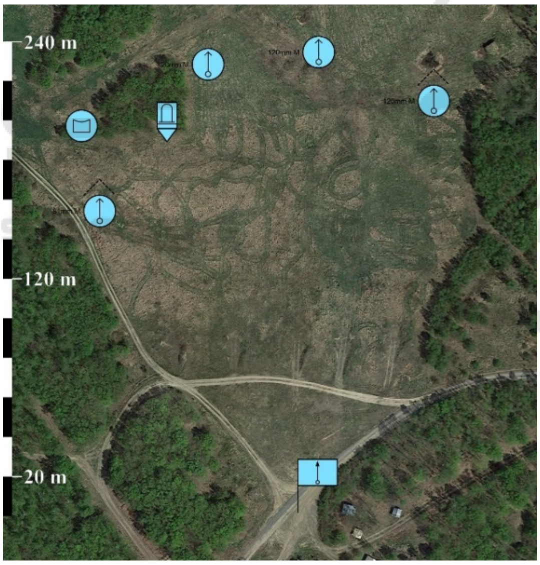

Figure 1: Tactical diagram of object positions with distance scale within the experimental area.

A total of six objects representing either real or decoy military targets were deployed within the observation area, as illustrated in Figure 1**.** Each object employed a different camouflage method:

1. Decoy light mortar position (81mm), constructed using a black plastic tube simulating a mortar barrel, with dimensions corresponding to a real weapon system. The object was placed approximately 180 meters from the observation post.

2. Command-type Vehicle, concealed under a camouflage net, positioned at the edge of a forested area. The vehicle represented a typical light tactical automobile. The distance from the observer was approximately 230 meters**.**

3. Supplementary Material commonly used at firing positions, including ammunition crates and packaging containers for transport and storage purposes.

4. Medium Mortar Position (120mm), located in a transition zone between forest and open terrain, with a single crew member kneeling next to the weapon system. The observation distance was approximately 250 meters**.**

5. Camouflaged Medium Mortar Position (120mm) in open terrain, utilizing natural vegetation (grass cover) for concealment. The object was situated at a distance of approximately 310 meters from the observation point.

6. Decoy Medium Mortar Position, constructed from natural materials (logs) cut and arranged to simulate the dimensions of a real mortar system. The decoy was placed at approximately 360 meters from the observer.

An example of natural camouflage and the use of a technical camouflage system is shown in Figure 2**,** which depicts a camouflaged mortar concealed with natural vegetation and a command-type vehicle covered with a camouflage net.

Figure 2: Observed objects camouflaged using natural materials and camouflage net.

3.2.2 Classification and Description of Sensors

Due to the rapid advancement of technologies, detection methods used for identifying and evaluating the effectiveness of camouflage are continuously evolving. The selection of detection platforms is therefore a critical factor in the interpretation of results. Findings from this study may serve as a foundation for future improvements in military tactics and enhanced protection against modern reconnaissance systems.

The following detection systems were employed in the experiment, representing a spectrum of platforms commonly available within the armament of contemporary armed forces:

Human Eye – direct visual observation without any optical support.

Aiming Circle (PAB-2A) – featuring 8× magnification and a 5° field of view; used for general observation and orientation.

Standard Military Binoculars – 7× magnification with a 7.5° field of view; suitable for rapid terrain scanning and identification of large targets.

Spotting Scope Meopta MeoStar S2 82 HD is high-magnification (up to 70) optical device designed for detailed observation of distant targets.

Thermal Scope HIKMICRO Falcon FH25 – passive sensor for detecting heat signatures, enabling observation regardless of lighting conditions. The is a compact thermal monocular with a 384 × 288 px, 12 µm VOx sensor and thermal sensitivity of ≤ 20 mK. It features a 25 mm lens, 8× digital zoom, and a detection range of up to 1200 meters.

Multisensory Device MOSKITO – combines a daylight optical channel (8× magnification, ~6° field of view) and a thermal imaging sensor. In this experiment, optical channel was used for visual target identification.

Unmanned Aerial Vehicle (UAV) DJI Mavic 3 – equipped with a wide-angle camera and thermal sensor; manually controlled by the operator without automated data processing.

The **human eye**, as the most fundamental means of sensory perception, was employed as the primary tool for initial orientation and target acquisition. Despite its limited range and dependence on ambient lighting conditions, it remains a widely used method for rapid detection of targets in natural terrain.

Subsequently, an **aiming circle** was utilized. This instrument not only supports observation but also enables azimuth determination. While it plays an important role in the field orientation of artillery units, it was less frequently used by participants during the experiment.

A **multisensory system** combining optical and thermal imaging capabilities provided a comprehensive visual and thermal representation of the target, including distance estimation. Its functionality under reduced visibility and overall versatility made it one of the most preferred detection tools.

For spatial situational awareness, an **UAV** equipped with a camera and thermal sensor was employed. The UAV was manually piloted by the evaluator and enabled elevated-area observation based on operator discretion. All flights were conducted during daylight hours.

For detailed long-range observation, a **spotting scope** with high optical magnification was used. It enabled the identification of fine details that were not easily discernible with standard optics, including specific camouflage patterns and material structures.

A **thermal scope** was included in the sensor suite, offering the advantage of detection based on thermal radiation. It proved effective for revealing objects concealed by vegetation or camouflage materials especially targets such a humans and vehicles. Its independence from ambient light conditions was a significant benefit under reduced visibility.

The last tool included was a **standard military binocular**, which was frequently used by participants. It enabled the successful detection of even well-concealed objects, including a vehicle hidden at the forest edge.

3.2.3 Validity

To ensure repeatability and scientific validity, the experiment was designed in such a way that it could be replicated by other research teams under comparable conditions. All scenarios, environments, and configurations were meticulously documented. Internal validity was supported through the use of a controlled testing environment and standardized instructions provided to all participants**.** External validity was ensured by selecting test parameters that closely reflect real-world operational deployment scenarios of mortar units**.**

3.2.4 Observation Procedure and Applied Methods

Each participant began the observation phase using unaided vision, without any technical support. Subsequently, participants were allowed to choose the order in which to use the remaining observation tools based on personal preference. A maximum time limit of three minutes was allocated for the use of each tool to ensure uniform exposure and consistent use of observation time.

After using each detection system, participants recorded their observations in a standardized protocol, which included the following data fields:

- Type of identified target (e.g., firing position, vehicle, decoy, personnel, equipment);
- Observation tool used;
- Estimated distance to the target;
- Confidence level in detection, on a 1–5 scale.

The results indicate that participants likely selected observation tools based on familiarity and perceived ease of use:

- Aiming circle was frequently chosen as the second tool, possibly due to its simplicity of operation;
- Spotting scope dominated the third round of selections, reflecting its strength in optical magnification;
- Multifunctional sensor systems were more often used later in the process, suggesting a preference for simpler tools in the early evaluation stages;
- Thermal scope was selected in the later phases, likely due to their specialized capability in detecting heat signatures;
- UAV (drone) was most commonly deployed last, likely for targeted final-stage reconnaissance.

These conclusions are based on observed selection order, not on direct participant feedback. A comparison of detection success rates, error types, and subjective evaluations of each observation system is presented in Table 1**.**

Table 1: Sensor Preference Ranking Based on Participant Selection.

Selection Order	Most Frequently Selected Tool	Percentage of Respondents (%)
2nd Selection	aiming circle	35
3rd Selection	spotting scope	30
4th Selection	MOSKITO	45
5th Selection	thermal scope	30
6th Selection	UAV	25

The table provides a comprehensive comparative summary of individual observation systems in terms of detection success, error rates, and subjective reliability assessments. For each system, the table presents the percentage of successfully detected targets, the number of Type I errors (false detections), Type II errors (missed actual targets), and the average subjective confidence rating on a 1 to 5 scale.

The results reveal significant differences between the systems - some exhibit high detection capability and low error rates, while others are less reliable or more demanding to operate. The table thus offers an integrated comparison of both the technical effectiveness and the practical usability of each sensor under the conditions of a field experiment.

3.2.5 Detection Assessment

The evaluation of the detection capabilities of individual systems was based on three key variables: detection success (Yes/No), subjective confidence level, and the classification of detection errors - specifically, Type I errors (false identification of a non-existent object) and Type II errors (failure to detect an actually present target). Each entry in the observation protocol was further analysed with respect to the type of sensor used, the identified object category, and the estimated distance to the target.

For comparison purposes, the data were aggregated into a summary matrix tracking the performance of each observation system. The matrix includes:

- Percentage of correctly detected targets;
- Average subjective confidence rating (scale 1–5);
- Frequency of Type I errors (false positives) and Type II errors (missed detections);
- Detection success rates across different target types (e.g., actual firing positions, decoy targets, camouflaged objects).

Table 2: Results of the comparison of individual observation tools in terms of detection success, error rates, and subjective reliability assessment.

Observation Tool	Detection Success Rate (%)	Type I Errors	Type II Errors	Subjective Reliability (1–5)
Human Eye	92	5	3	5
Aiming circle	75	10	15	3
Spotting Scope	80	8	12	4
MOSKITO	88	6	6	5
Thermal scope	70	12	18	2
UAV	65	15	20	2
Binoculars	78	9	13	3

The results are evaluated using descriptive statistics, specifically arithmetic mean and standard deviation, and are compared both across observation tools and across target types. This approach allows for the identification not only of the overall effectiveness of each system but also its limitations in specific operational scenarios, such as lower confidence levels when detecting naturally camouflaged targets or higher false positive rates with decoy objects.

The analysis thus provides a quantitative basis for comparing the detection efficiency of individual sensors and enables an evaluation of the effectiveness of different camouflage techniques from the perspective of realistic operational application. A summary of these key indicators is presented in Table 2, which facilitates a comprehensive comparison of the observation systems in terms of reliability, accuracy, and practical usability under field conditions.

The table provides a comparative summary of observation tools based on detection success, error incidence, and subjective reliability ratings. For each system, it reports the percentage of successfully detected targets, the number of Type I errors (false detections), Type II errors (missed actual targets), and the average subjective rating on a 1 to 5 scale. The results show clear distinctions between the tools - some demonstrate high detection performance and low error rates, while others are less reliable or more demanding to operate.

This comparison enables a holistic evaluation of both the technical efficiency and field-level applicability of each sensor type in a live operational test environment. While this study focused primarily on detection success, future research will aim to quantify additional camouflage performance indicators, such as time-to-detection and targeting accuracy, and assess their statistical correlation with specific camouflage parameters.

4 RESULTS

Descriptive and inferential statistical methods were employed to process the collected data. Descriptive statistics were used to evaluate detection rates, error types, and the average subjective confidence levels reported by participants. To assess the statistical significance of relationships between variables, the chi-square test and one-way analysis of variance (ANOVA) were applied. The analysis of results considers both quantitative indicators and the interrelation between the type of camouflage, the observation device used, and the success rate of target detection.

As illustrated in Figure 3, the most frequently detected object across nearly all observational methods was the unconcealed mortar, confirming that the absence of camouflage significantly increases the probability of detection, regardless of the observation technology employed. The most effective tool for visual detection was revealed to be the human eye, which demonstrated the ability to rapidly and accurately identify visible objects in most cases. Notably, its performance surpassed that of certain technical devices, highlighting the importance of field experience and innate perceptual acuity in operational environments.

In contrast, camouflaged objects, particularly decoy positions, proved significantly more difficult for observers to detect. The highest detection success for such targets was achieved using the MOSKITO device, equipped with multisensory capabilities; however, even in this case, full and accurate identification was not consistently ensured. These results confirm that deception and natural camouflage techniques substantially reduce the probability of detection, especially when properly implemented.

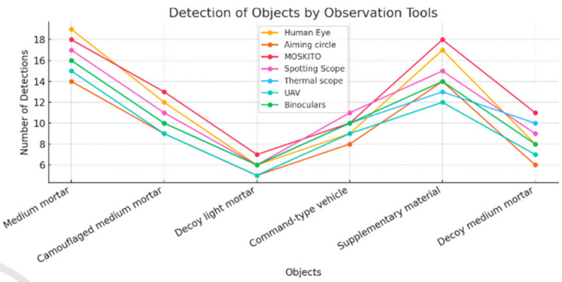

Figure 3: Detectability of individual targets based on the type of reconnaissance asset.

Table 3: Number of successful detections of individual targets by various reconnaissance assets.

Objects	Human Eye	Aiming circle	MOSKITO	Spotting Scope	Thermal scope	Binoculars
Medium mortar	22	12	18	16	19	20
Camouflaged medium mortar	6	7	8	6	10	7
Decoy light mortar	7	5	14	9	9	8
Command-type vehicle	11	9	12	14	15	19
Supplementary material	18	20	15	13	17	18

Participant preferences regarding the selection of individual observation tools are clearly illustrated in Table 3, which displays the sequence in which tools were used during the observation trials. The spotting scope demonstrated consistent, relatively low-selectivity performance. The number of detections was evenly distributed across different object types. This indicates its limited ability to distinguish between targets under specific conditions and suggests its suitability more for general observation rather than the targeted identification of concealed or decoy assets.

As part of the evaluation, participants' preferences in the sequence of observation tool usage were also monitored. Each participant began with unaided visual observation, followed by optional selection of additional tools according to personal judgment. The table below presents the most frequently chosen tool at each position in the selection order (e.g., second, third, etc.). The values indicate the percentage representation of each tool's selection at specific positions and serve primarily to interpret user decision-making behavior, rather than to evaluate tool effectiveness. An overview of these selection preferences is provided in Figure 4, which illustrates the distribution of tools according to their order of use.

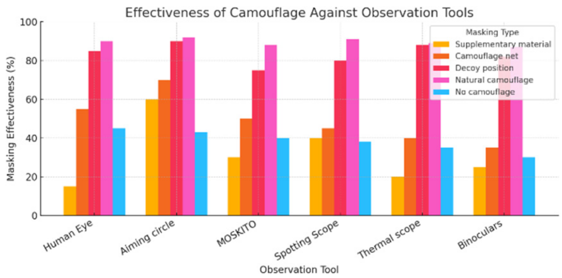

Figure 4: Comparison of the effectiveness of different camouflage types against various reconnaissance assets.

The data indicate that natural camouflage and decoy positions achieved the highest levels of concealment effectiveness, with strong performance across most observational tools. For instance, when using the naked eye, natural camouflage yielded nearly 90% concealment effectiveness, whereas an unconcealed mortar was detected in 100% of cases, underscoring the critical role of camouflage measures. Table 4 shows the percentage differences in detection success among observation tools across various target types, including those masked with natural materials or presented as decoys.

The MOSKITO multisensory device demonstrated high effectiveness in detecting decoy positions, but its performance decreased when identifying naturally camouflaged objects. Conversely, thermal imaging maintained relatively consistent results, although camouflage effectiveness was often lower, particularly for targets with more prominent thermal signatures.

An important observation is that certain tools such as the aiming circle showed lower success in detecting camouflaged or decoy targets, where concealment effectiveness reached up to 90%. This finding highlights the limitations of traditional optical instruments with narrow fields of view, which may not be suitable for identifying concealed objects in complex terrain.

Table 4: Detection rate and effectiveness of different camouflage types by reconnaissance system type.

Sensors / Camouflage	Human Eye	Aiming circle	MOSKITO	Spotting Scope	Thermal scope	Binoculars	Masking effectiveness (%)
Supplementary material	10 (10%)	20 (9%)	13 (5%)	13 (5%)	17 (15%)	18 (10%)	51.72%
Camouflage net	11 (11%)	9 (9.4%)	12 (5.4%)	14 (4.5%)	15 (6%)	19 (7.4%)	25.25%
Decoy position	7 (8%)	5 (9.8%)	14 (7.2%)	9 (7.9%)	8 (8.7%)	8 (7.1%)	52.00%
Natural camouflage	6 (8%)	7 (9.5%)	8 (6.4%)	6 (8.0%)	10 (8.3%)	7 (8.1%)	58.00%
No camouflage	22 (0%)	12 (5.5%)	18 (4.2%)	16 (7.3%)	19 (4.3%)	20 (9.1%)	0.00%

5 DISCUSSION

Although valuable insights were obtained, several limitations must be discussed, as they may influence the results and should be considered in their interpretation.

The experimental group consisted of 23 students with varying levels of familiarity and no standardized experience profile in the use of military optics. This variability may have affected individual target recognition performance and represents a methodological limitation of the study.

Another variable factor potentially affecting the results was the environmental condition and season in which the experiment was conducted. Testing took place in February during the winter when vegetation offered limited opportunities for natural concealment. The low density of vegetation increased the visibility of objects that, during other seasons such as summer, would typically be more difficult to detect due to denser foliage and different environmental color spectra. This factor may have influenced the effectiveness of natural camouflage and the ability to detect it. For this reason, it is recommended that the experiment be repeated. Conducting the study in summer conditions would enable a comparison with the winter variant and provide a more comprehensive understanding of camouflage effectiveness throughout the year.

The experiment was conducted as a single session under clear weather conditions, without precipitation, ensuring favorable lighting. Therefore, the results cannot be directly extrapolated to low-visibility scenarios, such as those involving rain, fog, or low-light conditions. Varying meteorological circumstances may influence both target visibility and camouflage effectiveness, and repetition of the experiment under different climatic conditions is thus warranted.

In future research, it would also be beneficial to broaden the sample of observers to include professional soldiers, reconnaissance specialists, or personnel from other combat-oriented military branches. This would allow for a comparative analysis of results across different levels of operational expertise.

A further research direction lies in evaluating the performance of combined camouflage techniques. Future studies could investigate the synergy between natural materials, camouflage nets, and decoy positions, and assess their resistance to detection by modern sensor systems, including thermal imaging, multispectral sensors, and unmanned aerial reconnaissance platforms. The outcomes of such research could be applicable not only to tactical military scenarios but also to civilian domains, such as infrastructure protection.

Overall, the findings confirm that the combination of decoy positioning and natural camouflage provides a high degree of protection, particularly against conventional optical surveillance systems. Although the deployment of modern sensors such as the MOSKITO or thermal imagers enhances the probability of detection, even these technologies are not fully reliable when faced with well-executed concealment techniques.

6 CONCLUSIONS

This experiment served as an initial phase in the validation of selected camouflage techniques under conditions approximating those of the contemporary battlefield specifically, in open and semi-covered terrain with seasonally limited vegetative cover. The data obtained provided useful pilot insights that underscore the significant contribution of natural camouflage and decoy positions in reducing the probability of detection, particularly with respect to optical systems and direct visual observation. In contrast, unconcealed positions were identified with high accuracy, confirming the critical role of camouflage in the protection of firing positions. For example, the use of natural camouflage reduced detection success rates by up to 35% across most sensor types, while decoy positions achieved an average concealment effectiveness of 70% based on observer ratings.

When comparing the performance of detection tools, thermal scope and the MOSKITO multisensory system emerged as the most effective. Conversely, the performance of optical devices and human observation was strongly influenced by the observers' individual experience and the specific conditions of observation. Nevertheless, even advanced sensors exhibited certain limitations when faced with well-executed camouflage, highlighting the importance of deliberate and adaptive concealment even against technologically sophisticated adversaries.

The partial results also reflect the influence of environmental and seasonal factors on camouflage effectiveness. The experiment was conducted during the winter months, when sparse vegetation provided minimal natural cover. It is reasonable to assume that denser foliage during the summer season may significantly enhance the effectiveness of natural camouflage techniques however, this assumption requires further experimental verification.

Based on the results obtained so far, it can be concluded that effective concealment in the operational environment necessitates a combination of multiple techniques, with an emphasis on adaptation to current conditions. The observed influence of the human factor including the observers' individual skills, knowledge, and perceptual abilities remains a significant variable in the detection process.

Future research should focus on expanding the experimental framework: including a broader and more diverse sample of observers (e.g., active-duty military personnel), conducting trials in varied climatic and terrain conditions, and incorporating a wider range of detection systems, such as multispectral sensors and unmanned aerial platforms.

The experiment was designed with a strong emphasis on repeatability and methodological rigor. All scenarios and conditions were meticulously documented to enable replication by other research teams under comparable settings. Internal validity was supported through a controlled environment and standardized instructions for all evaluators, while external validity was reinforced by selecting conditions reflective of real-world deployment scenarios encountered by mortar units.

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