LXXVI. ÉVFOLYAM 2024. különszám

HONVÉDORVOS

A MAGYAR HONVÉDSÉG EGÉSZSÉGÜGYI KÖZPONT, A NATO KATONA-EGÉSZSÉGÜGYI KIVÁLÓSÁGI KÖZPONT ÉS A MAGYAR KATONAI- KATASZTRÓFAORVOSTANI TÁRSASÁG LAPJA

ZRÍNYI KIADÓ

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2024. évi különszám

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Szerkesztőség

Implementing Advanced Distributed Learning: A Case Study from Vigorous Warrior 2024 and Clean Care 2024 Exercises

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Keywords education, eLearning, advanced distributed learning (ADL), joint military exercise, NATO, flexible learning

Abstract *Multinational military exercises inherently bring together participants with diverse backgrounds, experience levels, and knowledge bases, creating challenges in achieving uniform preparedness. The pre-training phase plays a critical role in equipping participants for effective engagement in these exercises. Furthermore, the evolving nature of military operations—characterized by increasing multinational collaboration and operational complexity—necessitates innovative training approaches, rapid skill acquisition, and adaptability.*[1] *Integrating Advanced Distributed Learning (ADL) into multinational exercises represents a critical step in meeting these demands.*[2]

This case study focuses on the implementation of ADL in the Vigorous Warrior 2024 and Clean Care 2024 (VW24/CC24) joint multinational exercises. For the first time, these exercises incorporated an eLearning platform to support pre-training requirements and serve as an asset during and after the exercise. Designed to cater to both the Training Audience (TA) and Exercise Control (EXCON), the platform was accessible to civilian and military participants alike.

The authors present key lessons identified from the operational integration of ADL into VW24/CC24 and analyze its impact on the exercises. The study also highlights insights derived from learning analytics, including data collected from eLearning courses, illustrating the potential of ADL to enhance preparedness, streamline training, and support knowledge retention in complex multinational contexts.

1 Presnall, Biljana, Baker, Ryan: *Mapping eLearning Preparation to Training Objectives in a Multinational Exercise: A Q-Matrix Approach.*

2 Salkutsan, Serhii et al.: *Enhancing Military Exercise Team Performance with Diversified xAPI Instrumented eLearning.*

INTRODUCTION

The emergence of the COVID-19 pandemic[3] in 2020 led to the widespread cancellation of training courses globally. Training providers, schools, academies, and universities faced a shared challenge: how to deliver effective education and training under uncertain and rapidly changing circumstances. To address this, many institutions—public and private, civilian and military—were compelled to adopt fully online or hybrid learning formats to maintain continuity.

NATO institutions were no exception. They adapted by transitioning to virtual education and leveraging existing online learning capabilities. For the NATO MILMED COE, this unprecedented situation prompted a comprehensive review of its education and training delivery methods. It became evident that online courses and virtual learning opportunities were not merely stopgap solutions but valuable tools that could play a central role in areas like theoretical education. Recognizing this potential, NATO MILMED COE committed to embracing virtual education as a core component of its future strategy to deliver cost-effective, efficient, and modern training solutions through technology, digitization, and innovation.

As a first step, NATO MILMED COE began developing standalone online courses that could seamlessly integrate into blended learning programs. These courses were designed to support existing training by providing pre-learning material and foundational knowledge. By 2022, the focus expanded to exploring how ADL could enhance multinational exercises, specifically in the context of VW24/CC24.

In military exercises, the planning team must dedicate significant time and resources to bringing the training audience up to speed—a task that often detracts from other activities that could enrich the exercise and enhance learning outcomes. This challenge is particularly pronounced in multinational events, where participants bring diverse backgrounds, varying levels of knowledge, and different prior experiences.[4]

Automated eLearning courses provide a practical and efficient solution to this challenge. By supporting the pre-training phase, eLearning helps participants quickly gain the foundational knowledge needed to engage effectively in the exercise. Beyond pre-training, eLearning also proves valuable during and after the exercise. It facilitates just-in-time learning, enabling participants to access critical information when needed, and serves as a resource for after-action reviews and refresher training.

Moreover, in an era where the nature of warfare is rapidly evolving, the need for adaptive and effective training solutions is more critical than ever. eLearning represents a strategic asset in addressing this need, enabling training programs to be scalable, responsive, and aligned with the demands of modern military operations.

In the remainder of this article, we detail how ADL capabilities were integrated into the pre-training phase of the

3 Coronavirus disease 2019 (COVID-19) is a contagious disease caused by the coronavirus SARS-CoV-2.

4 Jefferson Institute: *ADL in exercises.*

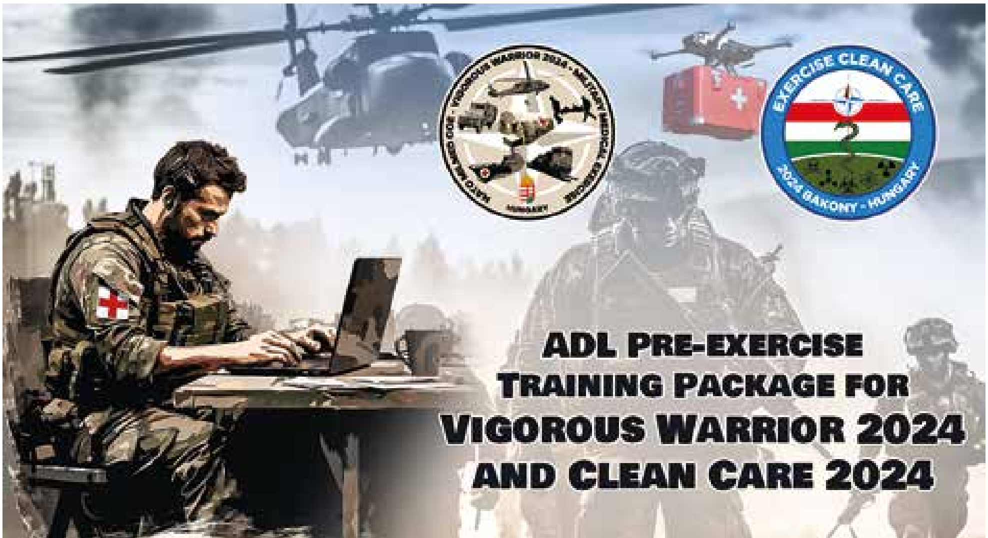

Figure 1: Banner_ADL Pre-exercise Training Package for VW24/CC24 (Photo by Lt. Ákos Szénási)

VW24/CC24 exercises, demonstrating their effectiveness in preparing participants for these complex multinational scenarios.

VIGOROUS WARRIOR (VW) EXERCISE

The Vigorous Warrior (VW) exercise series is NATO's largest multinational medical exercise, organized biennially by the NATO MILMED COE in collaboration with a voluntary host nation. The exercise addresses some of the most pressing challenges in the military-medical field within a multinational context under NATO's auspices. Its primary objective is to enhance the efficiency and interoperability of military medical support systems during NATO Major Joint Operations by simulating a complex, joint operational environment.

VW provides participating NATO and partner nations with the opportunity to train together in a realistic Article 5 scenario, practicing the full spectrum of medical support operations—from planning to surgical intervention—under realistic conditions. Participants not only engage in hands-on medical operations but also contribute to concept development, experimentation, and the testing of interoperability skills with other nations.

The VW24 exercise was particularly notable because it was conducted in conjunction with the Clean Care 2024 (CC24) chemical, biological, radiological, and nuclear (CBRN) exercise. This combined event took place in Bakonykúti, Hungary, in May 2024, creating a unique setting that brought together 1,600 participants from 35 nations. By integrating these two exercises, VW24 demonstrated the value of collaborative training in addressing complex, multidimensional operational challenges.

Figure 2: VW24/CC24 in Bakonykúti, Hungary, 4–8 May 2024 (Photo by Lt. Ákos Szénási)

ADL COMPONENT IN VW24 AND CC24

For the first time, the NATO MILMED COE introduced eLearning courses as part of the pre-exercise academic training for VW24/CC24. Using an ADL package, the pre-training phase was designed to orient exercise participants flexibly, effectively, and cost-efficiently. The primary goal was to ensure that both the Training Audience (TA) and Exercise Control (EXCON) staff shared a common operational understanding before the exercise began. Additionally, the ADL package aimed to reduce time spent on in-person academic instruction during the exercise, enabling more time to focus on other critical elements of the event.

To deliver effective eLearning resources, the Core Planning Team (CPT) of VW24/CC24 assigned the NATO MILMED Training Branch Course Developer to manage the integration of ADL. The project received critical support from the US Army Combat Capabilities Development Command (DEVCOM), with the Jefferson Institute, a Washington-based independent research and education organization, acting as a liaison. Although their involvement began late in the planning phase, their contributions significantly shaped the ADL components. Their support included:

- Designing and developing pre-training eLearning content.
- Assisting with the collection of standard-based learning analytics data.
- Visualizing these analytics within an exercise dashboard for real-time insights.

Throughout the planning phase, key events such as the Initial Planning Conference, Main Planning Conference, and Final Coordination Conference included the ADL initiative on the agenda. These meetings allowed updates to be shared on project progress and alignment with exercise objectives.

The ADL implementation timeline for VW24/CC24 was synchronized with the exercise's planning, execution, and evaluation phases, following the guidelines outlined in the Advanced Distributed Learning in Exercises Annex to the NATO ADL Handbook.[5] This annex serves as a practical framework for integrating ADL into exercises, providing guidance on planning, execution, and evaluation. It also offers insights for both ADL and exercise teams to effectively incorporate eLearning tools into training processes. Following these guidelines, the NATO MILMED COE ADL development team successfully integrated ADL into VW24/CC24, enhancing the overall efficiency and impact of the exercises.

ONLINE COURSES IN THE PRE-EXERCISE TRAINING PACKAGE

The core concept behind the ADL Pre-Exercise Training Package was to adapt topics traditionally presented in person by Subject Matter Experts (SMEs) during the Academic Phase of the exercise into an online format. This approach allowed participants to complete essential preparatory training flexibly and independently, ensuring a baseline of knowledge before the exercise began. All courses were delivered in English, with no translations provided, and the package was divided into two categories: "Need to Know" courses and "Enabling" courses.

"Need to Know" courses

These mandatory courses were required for all exercise participants and provided fundamental knowledge about key aspects of the exercises. The seven offered modules addressed critical roles, responsibilities, and processes during the exercise.

For example, "Introduction to VW24 and CC24" gave an overview of the key elements of the exercise, while "Exercise Evaluation (EXEVAL)" explained the evaluation process and criteria, and "Medical Lessons Learned" introduced participants to NATO's Lessons Learned methodology and its application in exercises.

To achieve the completion certificate, participants had to finish all seven modules, which collectively required an estimated 3–4 hours. An additional "Medical Evaluation (MEDEVAL)" course was mandatory for personnel directly involved in medical evaluation, requiring approximately 60 minutes to complete.

5 *Advanced Distributed Learning in Exercises*, Annex to NATO ADL Handbook.

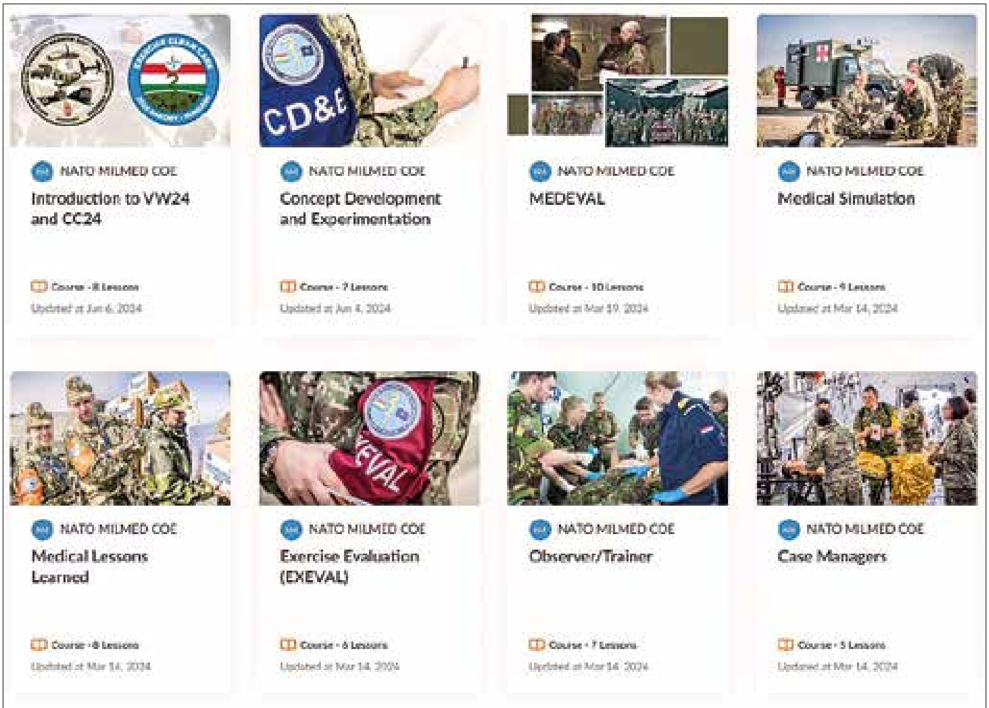

Figure 3: Courses of ADL Pre-exercise Training Package (Source: NATO MILMED COE)

The scope and length of the "Need to Know" courses were intentionally limited to focus on content relevant to the exercise. These courses were developed based on curricula provided by SMEs and adhered to pedagogical and instructional design principles.

"Enabling" courses

These optional courses were recommended but not required, offering participants the opportunity to explore supplementary topics. They included some essential information about NATO's functions as "Introduction to NATO" or awareness of integrating gender perspectives to improve operational effectiveness.

These courses were outsourced and as the NATO MILMED COE was not the content provider, the participation could not be tracked. However, they were made available to participants seeking a broader understanding of NATO structures, policies, operations, or contemporary Alliance issues.[6]

6 *Joining Instruction to ADL Pre-exercise Training Package for Vigorous Warrior 2024 and Clean Care 2024.*

IMPLEMENTATION AND LEARNING MANAGEMENT SYSTEM

The Joint Advanced Distributed Learning (JADL) platform, NATO's official Learning Management System (LMS), was chosen for delivering the ADL Pre-Exercise Training Package.[7] This platform facilitated seamless content delivery and user engagement, ensuring that participants could access the training materials efficiently and effectively.

The educational material was made available on JADL starting six weeks prior to the exercise, giving participants ample time to complete the required courses. The availability of the ADL package was extended until three months after the exercise, allowing participants to revisit the content for review, after-action analysis, or refresher purposes.

The courses were designed to be self-paced, enabling learners to progress through the material at their own speed and on their own schedule. This flexibility was particularly important given the diverse professional commitments and time zones of the multinational

Figure 4: Medical Lessons Learned course (Source: NATO MILMED COE)

7 https://jadl.act.nato.int

participants. Importantly, the courses did not require active instructor engagement, which streamlined delivery and further enhanced scalability.

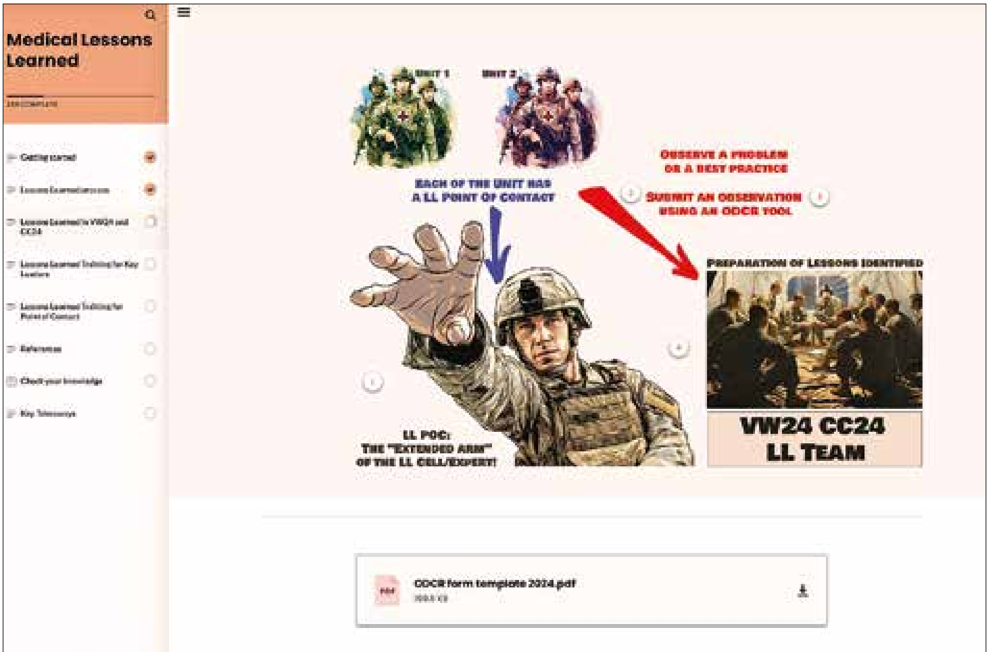

Figure 5: Medical Lessons Learned course (Source: NATO MILMED COE)

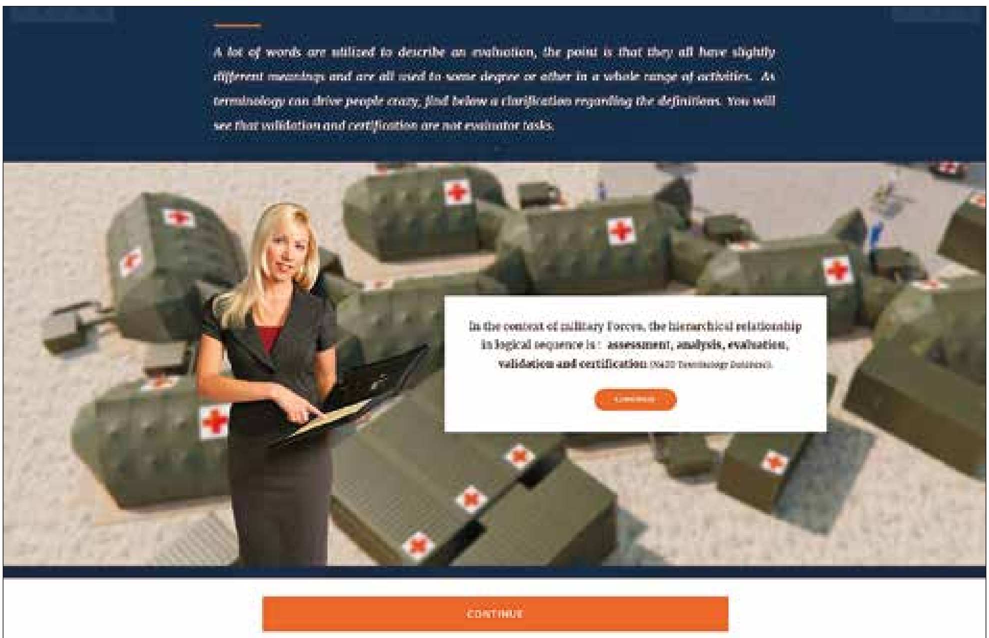

Figure 6: MEDEVAL course (Source: NATO MILMED COE)

Figure 7: Introduction to VW24/CC24 course (Source: NATO MILMED COE)

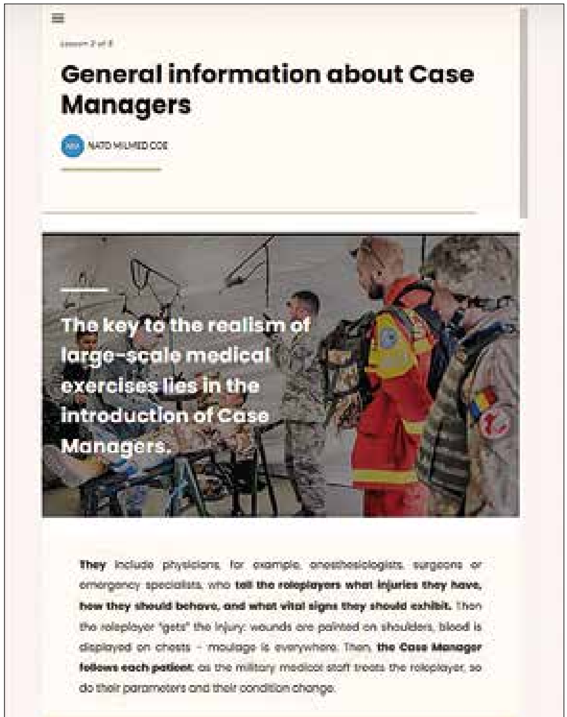

Figure 8: Case Managers course (Source: NATO MILMED COE)

JADL provided a comprehensive eLearning service, supporting all the essential components required for effective online education and training. Its features included:

- Course Delivery: Accessible modules with an intuitive interface for participants to navigate through the training material.
- Learning Progress Tracking: Detailed tracking and monitoring of individual progress, ensuring participants completed the required courses.
- Customizable Areas: Capability to tailor course layouts and content areas to meet the specific needs of the exercise.
- Forum Functionality: Enabling peer-to-peer interaction, discussion, and support, which enhanced collaboration among participants.
- Reference Material Upload: Easy sharing of supplementary documents, guides, and resources to enrich the learning experience.
- Data and Statistics Extraction: Comprehensive analytics tools for gathering insights into participation, completion rates, and learning outcomes, which informed post-exercise evaluations and improvements.

The JADL platform's modern interface and robust functionality ensured an accessible and user-friendly experience for all participants. Self-paced learning modules were accompanied by progress indicators and completion certificates,

Figure 9: ADL Pre-Exercise Training Package course page (Source: JADL)

motivating users to engage with the content thoroughly. Additionally, the platform's ability to integrate with other NATO systems ensured that data could be aggregated and analyzed efficiently, supporting both operational and strategic objectives.

While the JADL platform provided a solid foundation, the implementation process revealed key considerations for future improvements:

1. User Onboarding: Ensuring all participants were familiar with the platform's functionalities required additional effort, particularly for those less experienced with online learning systems.
2. Technical Support: Addressing connectivity issues and ensuring consistent platform availability were critical to maintaining engagement across different regions.
3. Content Adaptation: Designing materials to be engaging for a diverse audience emphasized the importance of multimedia elements and interactive components.

EVALUATION OF THE ADL PRE-EXERCISE TRAINING PACKAGE

The ADL Pre-Exercise Training Package was evaluated to measure its effectiveness, user experience, and areas for improvement. Feedback was gathered through participant interviews, usage data, and a structured post-course evaluation survey.

Despite some challenges, the level of engagement exceeded initial expectations for this first deployment of the ADL capability. A total of 477 users accessed the platform, completing 8 courses with a total of 3,131 completions recorded. The breakdown of course participation showed varying levels of engagement:

- The Introduction to the VW/CC24 course was the most completed, with 428 participants.
- The MEDEVAL course had the lowest completion rate at 253 users, which was expected as it was only required for personnel involved in medical evaluation.

These results highlight a positive initial uptake of the eLearning platform while underscoring the need to improve engagement and participation rates further.

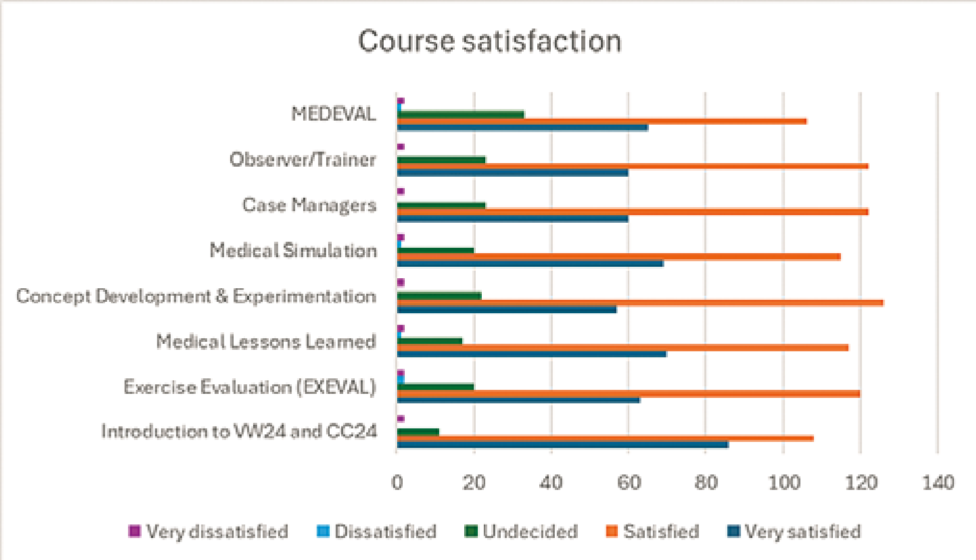

Figure 10: Survey Analysis – Course Satisfaction

To gather detailed feedback, a Post-Course Evaluation survey was administered through the JADL platform. The survey focused on key aspects of the user experience, including course structure and content, visual design, eLearning path and navigation, quizzing, multimedia and interactivity, and overall experience.

The survey design featured single-choice questions, 5-level Likert scale ratings, and optional comment sections for qualitative feedback. Out of the 477 users, 207 completed the survey, providing a representative sample for analysis:

- Overall Feedback: The platform received overwhelmingly positive reviews, with participants expressing high appreciation for its quality, relevance, and usefulness in preparing for the exercise.
- Technical Issues: Some users reported technical difficulties with the JADL platform, which occasionally affected their learning experience.
- Content Gaps: Participants requested additional resources and clearer guidance on course selection and supporting documents. Suggested additions included:
  - An introduction to military medical terminology for civilian participants.
  - A summary of EXCON structure, roles, and planning cycles to improve understanding of organizational processes.
  - A remedial Military Medical English course to support non-native English speakers.

Overall opinions of the platform were very positive, and its usefulness and quality were highly appreciated. Some participants indicated technical issues with the JADL eLearning platform. The users indicated requirements for more content in the platform, clearer guidance on what courses to take, and what documents to read. Additional content might include an introduction to military medical terminology for civilians; a summary introduction to the structure, organization, and various component roles and planning cycles of EXCON; and remedial Military Medical English.[8]

The evaluation results underline the success of the ADL Pre-Exercise Training Package in meeting its primary objectives while revealing areas for enhancement. Moving forward, addressing technical issues, expanding content offerings, and improving guidance for users will further optimize the platform's impact. These adjustments, combined with ongoing participant feedback, will ensure that future iterations of the ADL package continue to evolve as a key component of NATO multinational training exercises.

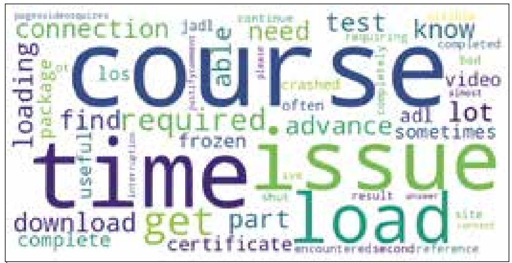

Figure 11: Wordcloud of ADL participant comments

LESSONS LEARNED

The use of ADL in VW24/CC24 proved to be a cost-effective, flexible, and essential tool for supporting exercise preparation. However, its potential extends beyond pre-training; ADL can also serve as a powerful performance support tool, enabling better outcomes during live exercises. To fully harness this capability, future iterations must incorporate the following lessons:

1. Integrate ADL Into the Planning Phase by following guidelines developed by NATO:[9]

– ADL should become an integral component of the planning process for the next iteration of the exercise of Vigorous Warrior and/or Clean Care.

– Establishing an ADL Working Group (WG) will ensure dedicated focus on this capability. This group should appoint representatives to the Exercise Planning Group (EPG) and work collaboratively to align eLearning efforts with broader exercise objectives. Aligning eLearning efforts with training objectives can significantly increase performance in exercises.[10]

2. Expand and Optimize eLearning Content

– The scope of e-learning should be broadened to include mandatory and optional microlearning courses, tailored to the exercise's Training Objec-

8 NATO Centre of Excellence for Military Medicine: *Final Exercise Report*.

9 *Advanced Distributed Learning in Exercises*, Annex to NATO ADL Handbook.

10 Presnall, Biljana, Baker, Ryan: *Mapping eLearning Preparation to Training Objectives in a Multinational Exercise: A Q-Matrix Approach*.

tives and themes. Diversified eLearning content has proven beneficial in tactical exercises.[11]
- Mandatory courses should focus on critical content that all participants must understand, while optional modules can provide supplementary knowledge.
- Careful consideration is needed to limit the number of required courses, ensuring participants can realistically complete them within their schedules.

3. Improve Strategic Communication
- Despite efforts to inform unit commanders about the ADL package, low participation stemmed primarily from a lack of awareness. Accessibility issues with the JADL platform may have also contributed.
- To address this, the importance and added value of ADL must be communicated early and clearly, emphasizing that mandatory eLearning content must be completed prior to the exercise.
- These requirements and expectations should be formalized in official exercise documents, such as the Exercise Specification Document, to ensure consistent messaging.

4. Measure Training Effectiveness
- Future exercises should incorporate mechanisms to evaluate the training effectiveness of ADL courses, not only in the pre-exercise phase but also during live events. Collecting data on participant performance and applying lessons learned will further refine the eLearning approach.

SUMMARY

ADL is about much more than cost reduction; it represents a transformative approach to military training, allowing content to be scaled and personnel to adapt rapidly in dynamic environments. The eLearning initiative in VW24 and CC24 was a critical step in integrating ADL in multinational exercises.[12] Its objectives were threefold:

1. Support the pre-exercise preparation of the Training Audience and Exercise Control (EXCON) staff.
2. Reduce the time spent on academic instruction during the exercise.
3. Enhance the quality of learning outcomes.

These objectives were largely achieved and deemed relevant and useful by participants, but the experience revealed opportunities for improvement.

To maximize the potential of ADL, future exercises must embed it more deeply into the planning and execution phases, ensuring all participants and stakeholders recognize its value. Data analytics and insights derived from ADL can further enhance exercise effectiveness, offering actionable intelligence to improve both training content and delivery. By building on the lessons identified, NATO MILMED COE can continue to innovate in training and prepare military personnel for the complex challenges of modern operations.

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11 Salkutsan, Serhii et al.: *Enhancing Military Exercise Team Performance with Diversified xAPI Instrumented eLearning.*

12 Ljung, Niclas et al.: *Integrating Advanced Distributed Learning into Multinational Exercises.*

ACKNOWLEDGEMENTS

Special thanks to the Jefferson Institute and U.S. Army DEVCOM. Collaboration with partners like them added significant value to the NATO MILMED COE effort. Maintaining and expanding these partnerships will be pivotal in refining and advancing ADL integration for Vigorous Warrior 2026 and beyond.

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ONLINE KÉPZÉS MEGVALÓSÍTÁSA: ESETTANULMÁNY A VIGOROUS WARRIOR 2024 ÉS A CLEAN CARE 2024 GYAKORLATOKBÓL

Szerzők Kucsmik-Horváth Éva, NATO Katona-egészségügyi Kiválósági Központ
Biljana Presnall, Jefferson Intézet (USA)

Kulcsszavak oktatás, eLearning, Advanced Distributed Learning (ADL), közös hadgyakorlat, NATO, rugalmas tanulás

Absztrakt *A többnemzeti hadgyakorlatok természetüknél fogva összehozzák a különböző hátterű, tapasztalati szintű és tudásbázisú résztvevőket, kihívást jelentve az egységes felkészültség elérésében. A gyakorlatokat megelőző képzési fázis kritikus szerepet játszik abban, hogy a feladatokra delegáltak hatékonyan tudjanak részt venni ezeken az eseményeken. Az ezen szakaszt támogató erőforrásoknak intuitívaknak, hozzáférhetőknek és könnyen navigálhatóknak kell lenniük a kihívások kezeléséhez. Ezenkívül a katonai műveletek változó jellege – amelyet a növekvő multinacionális együttműködés és a műveleti összetettség jellemez – innovatív képzési megközelítéseket, gyors készségszerzést és alkalmazkodóképességet tesz szükségessé. Az Advanced Distributed Learning (ADL) – E-learning/online képzés – integrálása a többnemzeti gyakorlatokba kritikus lépést jelent ezen igények kielégítésében.*

Ez az esettanulmány arra összpontosít, hogy milyen formában valósult meg az ADL alkalmazása a Vigorous Warrior 2024 (VW24) nemzetközi katona-egészségügyi NATO-gyakorlat során, amely esemény különlegessége az volt, hogy a Clean Care 2024 (CC24) vegyi, biológiai, radiológiai és nukleáris gyakorlattal közösen hajtották végre. Ezek a gyakorlatok először használtak eLearning platformot a képzés előtti követelmények elsajátítására, amely hasznos eszközként szolgált a katona-egészségügyi esemény végrehajtása során és után is. A Training Audience (kiképzendő állomány) és az Exercise Control (a gyakorlatot irányító állomány) számára kialakított online felület polgári és katonai résztvevők számára egyaránt elérhető volt.

A cikkben a szerzők bemutatják az online képzés VW24/CC24-be történő hatékony beillesztésének legfontosabb tanulságait, és elemzik annak a gyakorlatokra kifejtett hatását. A tanulmány emellett kiemeli a tanuláselemzésből származó meglátásokat, beleértve az eLearning kurzusokból gyűjtött adatokat, amelyek bemutatják az ADL-ben rejlő lehetőségeket a készenlét fokozására, a képzés egyszerűsítésére és a tudásmegtartás támogatására összetett, többnemzeti összefüggéseken keresztül.

30TH MULTINATIONAL MILITARY MEDICAL ENGAGEMENT SELECTED BRIEFS – SUMMARY

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KEYWORDS 30th MMME, military medicine, US-HUN military medical cooperation, medical research and science, scientific session, enabling the development of interoperability among medical services of NATO and partner nations, force health protection, medical aspects of the war in Ukraine, experience and dilemmas in the training of first care providers

ABSTRACT *The Medical Service of the Hungarian Defence Forces and the United States Army Medical Readiness Command Europe hosted the 30th Multinational Military Medical Engagement (MMME) in Budapest, Hungary, from 26 to 28 September 2023. The theme for the 30th MMME was "Culture and Change: Evolution of Civilian-Military Partnerships". The conference offered a three-day multinational dynamic program consisting of plenary sessions, panel discussions, exhibitions, and cultural events focusing on enhancing military medicine, interoperability, familiarization, and partnership-building through civil-military relationships. Selected conference topics are summarized and published by the author in this article.*

PART I
"TRAVEL THROUGH SCIENCE, CULTURE AND FRIENDSHIP, 1993-2023"[1]

The 30th MMME takes its roots in the first Gulf War. A 37-member strong Hungarian military medical contingent joined the coalition to free Kuwait after Iraq invaded it in 1990. The commander of the Hungarian military medical contingent was Colonel László Svéd, MD. The Hungarians served in cooperation with Polish, Philippine, Saudi, and American specialists in Saudi Arabia, at the Dhahran Air Base.

The last Scud missile landed in Dhahran, and the Patriot missiles failed to destroy it: the Scud slammed into the sleeping quarters of the barracks of the 14th Quartermaster Detachment (home station in Greensburg, PA) of the Pennsylvania National Guard – a unit which

1 SVÉD L. et al.: *Thirty years of US-Hungarian military medical cooperation and joint conferences from the First Gulf War to today.*

had deployed to the theatre three days earlier with the mission of making preparations for the troop withdrawal – where the whole personnel were already staying and relaxing. The missile, whose task was destruction and delivery of various agents of mass destruction instead of precision strikes, now hit the exact center of the barrack building. The immediate outcome was 28 soldiers killed and more than 100 injured. After a swiftly set up triage on the spot, the wounded were distributed among regional hospitals. We received 20 casualties until midnight, of whom eight were practically already dead on arrival.[2]

Figure 1: Logo of the first conference, 1993

The professional work and dedicated efforts of Hungarian colleagues in saving the lives of the casualties were recognized and highly appreciated by the US command officials, as well as the US medical personnel in the theatre of operation, and beyond. As a result, cooperation between the US and Hungarian Military Medical Services started after the war in the form of the American-Hungarian Military Medical Conference, first held in Balatonkenese, Hungary, on 19–23 September 1993 (see Figure 1), which became open to other states as of 2012. The conference was titled MMME in 2013, which is still in use today.

The most powerful engine, helper, and patron of the birth of the conference was Maj. Gen. Michael J. Scotti Jr., commander of the 7^{th} US Army Medical Service. He was a highly respected medical general with significant war experience, tremendous intelligence, and knowledge. Another key figure of the conferences was General Scotti's Vietnam war helicopter pilot, George Jászai, the predecessor of one of the most important organizers of our conferences for more than two decades, Mr. Mike Sandoval. The first conference was attended by 160 American/7^{th} MEDCOM physicians and their spouses headed by Maj. Gen. Scotti, and 60 Hungarian medical officers headed by Col. Svéd.

In preparation for the third conference, it was seriously raised that the conference should be expanded on a broader basis and possibly to include the medical services of the armed forces of several countries that were already on the verge of joining NATO. The possibility of expansion was examined by several people, and an agreement was reached that the Czech, Slovak, and Polish military medical services would also be invited to the third conference in 1995. This obviously involved careful preparations.

Two issues made this third conference remarkable – in addition to the fact that other Eastern European countries also participated in the event for the first time, General Scotti took part in the conference for the last time, and the entire staff of the congress laid a wreath at the monument of American heroes of World War II in Budapest (see Figure 2).

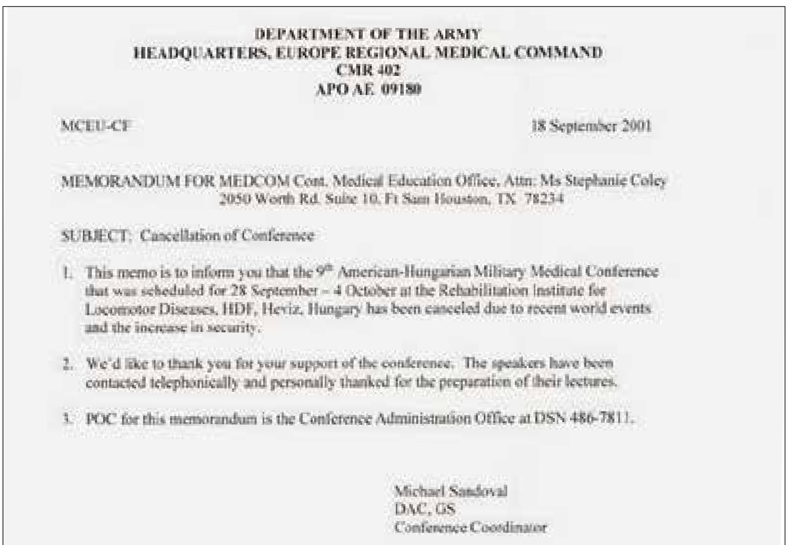
2 Svéd L.: *Hungarian Military Medicine in the First Gulf War.*

Figure 2: At the memorial, General Scotti pays his respects

The relevance of cooperation between US and Hungarian military medical personnel was well summarized in one sentence by Phil Gunby in an article published after the 6th conference held in Chiemsee, Germany, 13–17 September 1998. He wrote: “Military medical cooperation between the two nations is cited by US command officials in Europe as one of the leading success stories in the preparations for Hungary’s entry into NATO next spring.”[3]

A tradition was established to cover the same or similar topics in the agenda from two perspectives, both by a Hungarian and an American briefer. Accordingly, the topic of “Medical Lessons Learned in Bosnia-Herzegovina” was briefed by Maj. Gen. Svéd and Lt. Col. Jahns. Another topic, “Viral Hepatitis” was briefed by Dr. Makara from Hungary, which was followed by a brief about “Scrub Typhus” by Maj. McDonnell (USA) during the 7th conference in Balatonfüred, Hungary, 12–16 September 1999.

The “8th Annual American-Hungarian Military Conference” took place in Passau, Germany, 10–14 September 2000. The opening presentation by Brig. Gen. Ursone and Maj. Gen. Peake on September 11 turned out to be a prophetic one. The two US generals covered the issue of “U.S. Army Medical Doctrine: The Mass



DEPARTMENT OF THE ARMY
HEADQUARTERS, EUROPE REGIONAL MEDICAL COMMAND
CMR 402
APO AE 09180

MCEU-CF 18 September 2001

MEMORANDUM FOR MEDCOM Cont. Medical Education Office, Attn: Ms Stephanie Coley
2050 Worth Rd. Suite 10, Ft Sam Houston, TX 78234

SUBJECT: Cancellation of Conference

1. This memo is to inform you that the 9th American-Hungarian Military Medical Conference that was scheduled for 28 September – 4 October at the Rehabilitation Institute for Locomotor Diseases, HDF, Heviz, Hungary has been canceled due to recent world events and the increase in security.

2. We'd like to thank you for your support of the conference. The speakers have been contacted telephonically and personally thanked for the preparation of their lectures.

3. POC for this memorandum is the Conference Administration Office at DSN 486-7811.

Michael Sandoval
DAC, GS
Conference Coordinator

Figure 3: Memorandum for MEDCOM Continuing Medical Education Office, 2001

3 Gunby P.: *Physician Rapprochement Presaged NATO Entry.*

Casualty (MASCAL) response" in a 60-minute keynote presentation. A year later this topic became a harsh and tragic reality for the US and NATO (after the activation of Article 5 of the NATO foundational treaty by the USA).

After the attacks of 9/11, the US Conference Coordinator, Mr. Michael Sandoval issued a memorandum about the cancellation of "the 9th American-Hungarian Military Medical Conference" scheduled to take place at the Rehabilitation Institute for Locomotor Diseases of the Hungarian Defence Forces (HDF) in Hévíz, Hungary, 28 September – 4 October 2001 (see Figure 3).

The fact that the Hungarian colleagues were treated as equal partners by the USA was demonstrated every year through sharing US medical lessons from very recent incidents and current operations.

Col. Dr. Geiling delivered a 60-minute opening presentation about the "Pentagon Disaster" during the 10th Annual American-Hungarian Military Medical Conference in Grassau, Germany, 9–12 September 2002. During the next conference (7–12 September 2003) in Budapest, Hungary, Col. Moore of the 30th Medical Brigade briefed the audience on "Operation Iraqi Freedom (OIF) Medical Overview", while Col. Erickson and Lt. Col. Vetter from the U.S. Army Center for Health Promotion and Preventive Medicine presented "Epidemiologic Lessons Learned in OIF & Afghanistan".

Maj. Gen. Svéd, the Hungarian Surgeon General demonstrated his attentiveness during the 12th American-Hungarian Military Medical Conference in Budapest, Hungary (29 August–2 September 2004), when Col. (Promotable) Carla Hawley-Bowland, Commander of the United States Army Europe Regional Medical Command (ERMC), was notified about her promotion to Brigadier General (see Figure 4).

Figure 4: The cake presented to the ERMC Commander on the occasion of her promotion, 2004

The knowledge, experience, respect, encouragement, confidence, and connections gained by Hungarian colleagues during the years enabled the Medical Services of the HDF to establish a Centre of Excellence for Military Medicine (MILMED COE) and to run a NATO medical exercise.

This COE became a NATO-accredited education and training facility within a year after its establishment, a record-short period among the COEs around the Alliance. Col. Dr. István Kopcsó, the director, has briefed the "17th US-Hungarian Military Medical Conference" in Budapest, Hungary (8–11 September 2009) about "Recent Development and Current Challenges of MILMED COE". Col. Dr. Attila Lengyel (HDF) presented the topic "Vigorous Warrior 2011 – Multinational Medical Display: Experience and Results" during the 19th American-Hungarian Military Medical Conference in Budapest, Hungary (12–14 September 2011).

The annual American-Hungarian military medical conferences started to become truly multinational in 2012 (see Figure 5).

Figure 5: Poster of the 20th conference, 2012

In 2013, the conference was named MMME. Health and medical aspects of refugee management were covered first during the 21st MMME in Rose Barracks, Vilseck, Germany (15–17 September 2013). Lt. Col. Khaled Baltagi, Tunisia Ministry of National Defense, presented "Tunisian Military Health Service Response to the Refugees during the 2011–2012 Libyan Crisis".

The annual American-Hungarian military medical conferences served as educational platforms for the new generations of Hungarian medical officers, who dedicated their service to the management of the Medical Service of the HDF. Several of them were trusted to serve in command medical positions in the NATO Command Structure, as well as in the United Nations and the European Union. Brig. Gen. Dr. István Kopcsó, Medical Advisor and Assistant Chief of Staff/Head of Joint Medical Division, Allied Command Operations (ACO) briefed the 22nd MMME at the Supreme Headquarters Allied Powers Europe (SHAPE), 7–9 September 2014 about "ACO/SHAPE Medical Organization & Activities".

During the 23rd MMME (Budapest, Hungary, 13–16 September 2015) Maj. Zsolt Pető (HDF) presented the Hungarian view on an evolving issue among the allies, "Mission Impossible: Sustainable Rotation of Medical Personnel for Operations".

All of the participating nations benefited from the professional, scientific, and cultural potential of the MMMEs. Three more examples. The Slovak Armed Forces Surgeon General, Brig. Gen. Vladimír Lengvarský attended the 23rd MMME as well. In six years, he began to serve as the Minister of Health in the cabinet of Prime Minister Eduard Heger (between April 2021 and March 2023).[4] Maj. Gen. László Svéd (HDF) was elected to be the 3rd Chairman of the Committee of the Chiefs of Military Medical Services in NATO (COMEDS), which position he fulfilled from 2005 to 2006.[5] Brig. Gen. Zoltán Bubeník, the former Czech Surgeon General became the chief medical adviser to the North Atlantic Alliance as the 8th Chairman of COMEDS, the committee of Surgeons General of NATO and partner nations.[6]

The reader should be convinced already that MMMEs reflected vigorously

4 Vladimir Lengvarsky.
5 Committee of Chiefs of Military Medical Services in NATO.
6 Zoltán Bubeník.

the changes in the NATO security environment. Accordingly, the 24th MMME was dedicated to the "Rehabilitation of the Wounded Warrior: Care for the Visible and Invisible Wounds of War" (Armed Forces Recreation Center Garmisch, Garmisch, Germany, 11–14 September 2016). Col. Vsevolod Stebliuk (UKR) presented the topic "Challenges and Solutions in the Rehabilitation of Ukrainian War Casualties". Lt. Col. Andri Svets (UKR) briefed the audience about the "Ability to work under information overload of military personnel in 24-hour shifts". Capt. Éva Zsíros (HDF) presented "The Hungarian Border Barrier's position in Hungary".

The evolving security crisis in Ukraine required that the 25th MMME (Kyiv, Ukraine, 26–28 September 2017) had discussions on lessons of rehabilitation. Lt. Col. Mecketen (USA) presented the topic "Rules of War". Several speakers from the USA, HDF, UKR, and POL addressed the topic of care for and rehabilitation of wounded warriors. Lt. Konstiantyn Karpenko (UKR) highlighted "The Impact of Training on Soldier Survival".

The 26th MMME (Budapest, Hungary, 25–28 September 2018) saw the first presentation about a contracted medical support solution – "The KFOR contracted Role-2 Basic facility" by Col. Zoltán Vekerdi (HDF). This was the year when the MMME community thanked Mr. Mike Sandoval for his unwavering and invaluable contribution to the organization and management of the annual American-Hungarian military medical conferences and MMMEs. Mike, THANK YOU!

In a telegraphic style:

– 27th MMME (Lviv, UKR), Hetman Petro Sahaidachny National Army Academy, 17–19 September 2019, number of countries represented: 9, Regional Health Command Europe (RHCE) Commander: Brig. Gen. Ronald Stephens.

I.	1993. Balatonkenese		
II.	1994. Budapest		
III.	1995. Budapest		
IV.	1996. Ramstein		
V.	1997. Kecskemét		
VI.	1998. Chiemsee	XXI.	Vilseck, DEU
VII.	1999. Balatonfüred	XXII.	SHAPE, Mons, BEL
VIII.	2000. Passau	XXIII.	Budapest, HUN
IX.	2001. Hévíz (cancelled)	XXIV.	Garmisch, DEU
X.	2002. Grassau	XXV.	Kyiv, UKR
XI.	2003. Budapest	XXVI.	Budapest, HUN
XII.	2004. Budapest	XXVII.	Lviv, UKR
XIII.	2005. Garmisch-parten Kirchen	XXVIII.	Tbilisi, GEO
XIV.	2006. Budapest	XXIX.	Tartu, EST
XV.	2007. Regensburg	XXX.	Budapest, HUN
XVI.	2008. Budapest		
XVII.	2009. Budapest		
XVIII.	2010. Budapest		
XIX.	2011. Budapest		
XX.	2012. Landstuhl		

Figure 6: Dates and locations of the conferences

- 28th MMME (Tbilisi, GEO), Grand Sheraton Tbilisi, 31 May–2 June 2022, number of countries represented: 13, RHCE Commander: Brig. Gen. Mark Thompson.
- 29th MMME (Tartu, EST), Estonian National Defence College, 29 November–2 December 2022, Medical Readiness Command, Europe (MRCE) Commander: Brig. Gen. Clinton Murray.
- The dates and locations of the conferences can be found in Figure 6.

Measurable indicators of added value and effectiveness of the conferences include but are not limited to key medical positions in NATO, the United Nations, and the European Union, filled by medical professionals who grew in experience and knowledge through the MMMEs.

The most relevant success factor can be measured through the hearts and minds of all of us, who participated in the MMME activities. The continuity of the MMME conferences has served as a basis that enables our nations to strengthen the medical resilience of our societies, contribute to deterrence and defence of NATO, facilitate interoperability among our military medical services, and assist in preserving the safety and security of the trans-Atlantic region for the past thirty years and the decades ahead.

PART II
"PANEL DISCUSSION – EMERGING THREATS OF INFECTIOUS DISEASES (ID) IN THE OPERATIONAL ENVIRONMENT"

The second day of the 30th MMME was dedicated mainly to panel discussions. Brig. Gen. Clinton Murray (USA), Commander, U.S. Army MRCE chaired the panel. Lt. Col. Ágnes Guth-Orji (HDF) and Maj. Krisztina Szabó-Filyó (HDF) facilitated the discussions. RADM Charles Vitek (USA) contributed to the presentation that preceded the discussions. They highlighted emerging ID threats such as multidrug-resistant bacteria, especially those complicating combat-related injuries and blood safety, especially by transmittable viruses like Human Immunodeficiency Virus (HIV), hepatitis B and C, COVID-19, and malaria.

The context

Events over the last few years, including the pandemic and the war in Ukraine, have shaped how we view the current and future operational battlespace and the relevance of persistent and emerging ID threats. The world continues to wrestle with increasing antimicrobial resistance of bacteria, especially those associated with nosocomial infections within our healthcare facilities. This has become increasingly evident during the war in Ukraine. The prevalence of transmittable viruses in blood, required for life-saving interventions on the battlefield, demands continued focus on minimizing the threat of these viruses at national and international levels. In addition to transfusions, the risk of blood and bodily fluid exposure through sharps, needle sticks, or mucosal splashes must remain a priority to protect healthcare personnel, especially in deployed settings. Many lessons were learned during the COVID-19 pandemic, including challenges with logistical support, the capacity of the medical industrial base, and broad acceptance of force health protection measures. These lessons will impact future pandemics and large-scale combat operations, especially across Europe. Finally, we will continue to face historically relevant ID complications like malaria, which has seen increasing diagnosis, prevention, and treatment challenges.

Multidrug-resistant bacteria

Advances in casualty care have resulted in those injured on the battlefield surviving and recovering from their injuries better than in any war in history. However, the war in Ukraine is ushering in a return to large-scale combat operations and multidomain operations, which we did not experience during the wars in Iraq and Afghanistan. As such, we have to continue to learn from the lessons identified and apply them to future combat operations.

Although multidrug-resistant bacteria were seen during the wars in Iraq and Afghanistan, the scope and scale of the problem in Ukraine along with the movement of patients to civilian hospitals, including those across Europe, highlight the global threat. Of note, the presence of bacteria resistant to all approved antimicrobial agents is of great concern, especially with pathogens like *Klebsiella pneumoniae*, which acquire more virulence genes. The combination of virulence genes and antimicrobial resistance leads to excess morbidity and mortality from combat-related injuries. In addition, the movement of casualties across healthcare facilities can lead to nosocomial infections in other patients. This places a great emphasis on new antimicrobials and new diagnostic methods and enhances infection prevention and control measures at the individual and the facility levels both in fixed and mobile hospitals.

The US Centers for Disease Control and Prevention (CDC) are active in ten countries that arose from the former Soviet Union. CDC has offices in six of these countries, including a regional office in Tbilisi, Georgia that supports all ten countries.

Three of the disease threats are present in the region where the CDC is working with host governments to address antimicrobial resistance (AMR) in Ukraine, and two potentially blood-borne and sexually transmitted infections can be found at significant levels in Ukraine: HIV and hepatitis C.

Ukraine AMR

The Ukraine war has supercharged the AMR issue into a crisis with the large numbers of wounded patients overwhelming infection prevention measures in eastern hospitals. Large numbers of patients infected with highly resistant organisms are being transferred to western Ukraine hospitals and evacuated to neighboring countries.

– CDC is supporting an AMR project in 3 western oblasts.
– Task Force will develop a package of activities to:
  - Create multi-disciplinary teams in selected hospitals to strengthen AMR detection, clinical management, and facility-level infection prevention and control response.
  - Build a laboratory referral network for rapid pathogen identification and susceptibility testing using high throughput equipment including matrix-assisted laser desorption/ionization-time of flight (MALDI-TOF).
  - Introduce rapid reporting to clinicians in a user-friendly format.
  - Support regional Centers for Disease Control.

Blood safety

The wars in Iraq and Afghanistan revealed the need for blood product support far forward on the battlefield to save lives. The ability to provide whole blood or component therapy including packed red blood cells, platelets, and fresh frozen plasma near the time of injury clearly saves lives. However, the logistics of large-scale combat operations require a huge demand for blood collection and delivery along with blood collection nearer to the point of injury. This ushers in the threat of blood products not being fully tested for pathogens prior to transfusion, especially with HIV, hepatitis B, and hepatitis C.

The threat is significant in Europe when one considers the prevalence of HIV in Ukraine, which is second only after Russia with rates of 37.1/100,000 people and 40.1/100,000 people, respectively. This threat of viral infections also extends to blood and bodily fluid risks through sharp exposure, including needle sticks, and mucosal exposure through splashes. Rapid testing, field expedient treatment, and prevention are needed along with broad education of the forces.

Hepatitis C causes significant concern across the region as the overall prevalence of it is estimated to be 3 to 4 times the global average due to widespread infection, especially in the late Soviet and early post-Soviet period. Hepatitis C screening of blood products and decreased injection drug use have decreased new infections. In Ukraine, hepatitis C remains a significant health problem with an estimated rate of 3–4% of adults living with chronic hepatitis C infection.

A successful public health model has been demonstrated in Georgia that can lead to a rapid successful decrease in hepatitis C in the population. That model uses hepatitis C screening and confirmation and treatment with the currently available highly effective anti-hepatitis C medications, all provided to the patients for free, and with improved data systems to stop patients not receiving their test results or being lost before follow-up. This model could be implemented in Ukraine when the security situation allows.

The HIV epidemic in the Eastern European and Central Asian regions has significantly stabilized. New infections have decreased although the total number of people living with HIV continues to rise in many countries as people living with HIV/AIDS live much longer due to the antiretroviral therapy.

For example, in Ukraine, new infections are estimated to be less than new case detections (as detected cases include many persons who were infected years before). The overall prevalence is about 1% in the age group of 15–49 years.

COVID-19

Many of the challenges associated with COVID-19 will remain relevant for any future pandemic but also for large-scale combat operations. The inability of the medical industrial base to quickly develop and then manufacture key personal protective equipment, medical devices, medications, diagnostic platforms, therapeutic agents, and vaccines highlights future challenges that must be addressed. In addition, the challenges associated with the trust regarding the broad implementation of force health protection measures will impact the ability to broadly vaccinate at-risk personnel and broad acceptance of personal protective measures in the future.

The national and international public health and medical industrial base must be proactive in preparation for future pandemics and large-scale combat operations, otherwise there will be excess morbidity and mortality.

Malaria

Malaria has had a devastating impact on fighting forces throughout recorded history (see Figure 7). Despite all the advances in malaria diagnosis, treatment, and prevention, we continue to face increasing challenges from malaria in terms of adherence to personal protective measures like insect repellents and insect netting, taking prophylactic medications, and utilizing early diagnosis.

Of concern are the genetic changes in various malaria species that lead to failures of malaria Rapid Diagnostic Tests along with antimalarial prophylactic and treatment regimens. Although there is a vaccine used in Africa, it is not adequate to protect soldiers who are deployed to endemic regions. The challenges we face related to malaria are also present in the case of many other tropical and neglected diseases. We must continue to emphasize research and

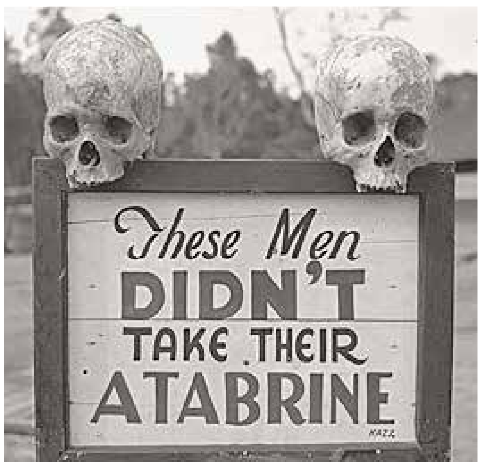


Figure 7: Warning and deterrent sign advocating protection against malaria in the Second World War
(A sign in front of the USA 363rd Military Station Hospital in Papua New Guinea in 1941. Available at http://rarehistoricalphotos.com/advertisement-atabrine-anti-malaria-drug-1941/ *Accessed: February 12, 2024)*

innovation along with command, with an emphasis on adherence to preventive measures to maximize combat power and performance on the battlefield.

Panel discussion conclusions

Infectious diseases remain an emerging threat to the operational environment, impacting combat performance and power. We must incorporate the lessons learned from the pandemic and the war in Ukraine into our civilian and military medical systems, our national and international public health communities, and our medical industrial base to mitigate excess mortality and morbidity of our fighting forces.

PART III "HOW TO TRAIN A MILLION SOLDIERS IN TCCC UNDER THE CONDITIONS OF A FULL-SCALE WAR?"

The third day of the conference started with the subject presentation about the efforts, achievements, and lessons in training UKR soldiers to provide tactical combat casualty care. The presentation was delivered by Leonid Kopus MD (UKR) and Igor Korpusov (UKR).

The context

The strength of the Armed Forces of Ukraine is classified information but according to various estimates, the approximate number of the troops reaches 1,000,000. All of them must be able to provide at least basic medical aid on the battlefield. Training such a large number of soldiers in tactical medicine under the conditions of a full-scale war is a problem that Ukraine has faced and must solve.

Private organizations – charitable and commercial organizations, state institutions, and international training missions – are trying their best to train Ukrainian soldiers in Tactical Combat Casualty Care (TCCC).

One such organization is PULSE.[7] Since the beginning of the full-scale invasion, more than 20,000 soldiers have been trained by PULSE within a 1.5-year period. PULSE sends mobile groups of instructors along with equipment to any point in Ukraine, which makes training flexible and convenient for military units. PULSE has the capacity to train 2,000 people per month and is constantly striving to increase this number because the demand is "crazy" and full of challenges.

7 PULSE – Tactical combat casualty care for Ukraine. https://www.pulse.charity/en

Security

The training location can be physically destroyed, so this must be considered during risk assessment and training planning.

Equipment

Training requires a large material base – training tourniquets, materials for wound packing, hundreds of liters of artificial blood, task trainers, and moulages for practicing skills, etc. – and, of course, ways to replenish the stocks.

Logistics

Flexible training planning is required due to the specifics of work in combat conditions. This is about situations when, for example, training is canceled at the last moment due to a change in the unit's plans. Or, on the contrary, there is a need to organize training in a few days.

Cadre

Training a large number of people requires a large number of instructors. PULSE considers the lack of high-quality instructors as the main problem. Since Ukraine must train a large number of military personnel (since the start of the full-scale war, more than 20,000 soldiers have gone through PULSE training alone), there is a need for a large number of instructors. Sometimes they must be prepared from scratch.

Categories

PULSE divides potential instructors into four main categories:

– those who have never been trained in tactical medicine;
– those who passed provider training but did not conduct training as instructors;
– those who already have teaching experience;
– war veterans.

Instructor training

The first two categories require the most attention, time, and resources in preparation. PULSE has come to a format in which the group of potential instructor candidates runs through provider training, then an instructor preparation course, and only the best ones remain in the course. After that, they become interns and teach under the supervision of senior instructors until they get enough experience. Instructor preparatory training can last from three weeks to several months.

Potential instructors from the 3rd and 4th categories (candidates with teaching experience or combat experience) might join the internship straightaway if they meet all the requirements.

Requirements

Experience and expertise, however, are not the only problems about human resources. Having experience in working with instructors who have worked a lot with the wounded, PULSE often comes across the problem of their motivation. This is related to the emotional component: they feel greater significance in directly practical activities. Therefore, instructors can periodically go on rotations as part of the medical evacuation team.

Resocialization of veterans as instructors

To work with veteran instructors, PULSE hired an experienced person with military experience who helps to adapt them to the organization. PULSE had several unsuccessful attempts to involve veterans, so it was decided to pay additional attention to this category of instructors.

Instructors' burnout

The work of PULSE instructors is connected with one-week or two-week trips. Training does not always take place in comfortable conditions. On average, an instructor spends 15–20 days working in a row, without days off. For instructors, PULSE tries to organize a balance between work, internal training, and rest. In PULSE's opinion, the ideal ratio is 2 weeks of work – 2 weeks of rest.

The way ahead

PULSE's current maximum training capacity is 2,000 servicemen per month, therefore, it would take 42 years to train 1,000,000 by PULSE alone.

PULSE is not alone

PULSE believes that it is possible to achieve the goal by taking certain steps, in particular:

1. Strengthening private organizations (charitable and commercial) as the most flexible.
2. Helping to develop governmental training centers. PULSE works on the training of instructors within selected units of the armed forces and helps find donors to provide such centers with the necessary training equipment in order to keep the TCCC training sustainable.
3. Exchanging experience with international initiatives that train Ukrainian military personnel to work according to standardized programs.
4. Paying more attention to the topic of tactical medicine in the media and social networks. There is a need to involve as many people as possible in TCCC to build a stronger community.

The future of MMMes

I am convinced that together we can and will sustain the high quality and added value of MMMEs for all participants and will ensure that this heritage-value scientific and team-building event continues to strengthen our trans-Atlantic bonds.

ACKNOWLEDGMENTS

The history of MMME conferences was summarized based on contributions, information, and materials kindly provided by Lt. Gen. (Ret.) Dr. László Svéd, MD (HDF), Sandoval, Michael E CIV (Ret) USARMY MEDCOM ERMC (US), and Lt. Col. (Ret.) Béla Cserenyecz (HDF).

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TÖBBNEMZETI KATONA-EGÉSZSÉGÜGYI KONFERENCIA – VÁLOGATOTT ELŐADÁSOK, ÖSSZEFOGLALÓ

SZERZŐ Dr. Vekerdi Zoltán orvos ezredes, NATO Katona–egészségügyi Kiválósági Központ

KULCSSZAVAK 30. MMME, katona-egészségügy, amerikai-magyar katonai orvosi együttműködés, orvosi kutatás és tudomány, tudományos ülésszak, a NATO és a partnerországok egészségügyi szolgálatai közötti interoperabilitás fejlesztése, haderővédelem, az ukrajnai háború orvosi vonatkozásai, tapasztalatok és dilemmák az elsősegélynyújtók képzésében

ABSZTRAKT *A Magyar Honvédség Egészségügyi Szolgálata és az Amerikai Egyesült Államok Haderejének Európai Egészségügyi Készenléti Parancsnoksága 2023. szeptember 26–28-án Budapesten adott otthont a 30., jubileumi Többnemzeti Katona-egészségügyi Konferenciának (Multinational Military Medical Engagement, MMME). A 30. MMME témaköre az egészségügyi biztosítás kialakult eljárásrendje és az abban megfigyelhető változások köré szerveződött. A háromnapos összejövetel változatos programot kínált, plenáris ülésekkel, panelbeszélgetésekkel, szakmai kiállítókkal és kulturális eseményekkel. A tudományos előadások középpontjában a katona-egészségügyi ellátás, az együttműködés, a polgári–katonai kapcsolatépítés és a partnerekkel való közös cselekvés kérdései álltak. Az összejövetelek elmúlt harminc évének történeti összefoglalóját és néhány kiragadott előadás bemutatását adja közre itt a szerző.*

The Impact of Space Missions on Humans1

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Abstract *From Yuri Gagarin's first manned spaceflight, the focus has been on investigating the function and changes in the human body across the full spectrum of spaceflight during all missions. Space travel impacts the whole body and affects all our organs and psyche without exception. As soon as we are exposed to microgravity and the Earth's gravity ceases to act on our bodies, we will notice changes such as osteoporosis (spaceflight osteopenia), a decrease in red blood cells (space anemia), and various symptoms observed during the missions, and the list goes on. Although many people are unaware that the benefits of space programs have affected almost everyone on Earth, the truth is that there is a wealth of inventions and discoveries that have come about solely because of space programs.*

INTRODUCTION

Human spaceflight has evolved significantly since its inception. Early space missions focused primarily on survival, as astronauts faced the challenges of launching into orbit, enduring the harsh space environment, and safely returning to the Earth. The first human spaceflight in 1961 marked the beginning of an era of exploration beyond our planet. Over the years, space agencies like NASA, Roscosmos, and others developed more advanced technology allowing longer missions and more complex tasks, such as spacewalks and docking at space stations. The creation of space stations like Skylab, Mir, and especially the International Space Station enabled humans to live and work in space for extended periods, advancing scientific research in microgravity. Today, human spaceflight is moving toward sustainability and permanence in space. The ISS (International Space Station) serves as a model for continuous human presence in low-Earth orbit. At the same time, upcoming missions aim to establish long-term habitats on the Moon (via NASA's Artemis program) and eventually Mars. These efforts require advancements in life support systems, radiation protection, and sustainable energy sources, as humanity pushes toward living and working in space indefinitely.

Researchers are using the data to develop even more effective procedures and equipment to help astronauts perform their tasks in a healthier manner. Engineers are also using the information to develop spacecraft and other life-support equipment that will ensure the long-term success of future missions. Ongoing research helps to improve and evaluate health standards, physical fitness programs, nutritional health protocols, and miscellaneous training standards. It is essential to understand the impact of space on humans, as we are about to leave the International Space Station in low-Earth orbit and head towards our next destination, the Moon. Missions lasting longer than a year have been carried out aboard the International Space Station to give researchers an even more detailed picture of what happens to our bodies when we live in this hostile environment for longer periods of time. Research has shown that a one-year mission has a different effect on humans, which is why exploring this area is essential if we are looking towards our even more distant goal of Mars.[1] NASA (National Aeronautics and Space Administration) is conducting continuous research on the risk factors for a trip to Mars and has grouped them. It is called RIDGE, which stands for Space Radiation, Isolation and Confinement, Distance from Earth, Gravity fields, and Hostile/Closed Environments.[2]

GO THERE AND COME BACK

From the very first moment, space travel is a stressful experience for the human body. Even the launch of a rocket is already an extreme load, while the body is subjected to several times the normal gravity. On Earth, under normal, resting conditions, we experience an acceleration of 1G (gravitational force). During the launch of a rocket, the human body can be subjected to an acceleration force of up to 4G. An unexercised person can tolerate approximately 3G, but above that, they may lose consciousness. The vertical G-force is harder to withstand than the force applied in a direction to the spine, as blood drains away from the brain and eyes. A significant G-force can have negative effects, such as the heart no longer being able to deliver blood efficiently to the organs, resulting in poor circulation and insufficient oxygen to the brain and other parts of the body. In more extreme cases, loss of consciousness may occur, often preceded by a deterioration in vision, such as tunnelization, or loss of color vision. Most spacecraft are designed so that the effect of the G-force is spread over a comfortable spectrum

*Figure 1: Inside the capsule (*https://www.russianspaceweb.com/soyuz-ms-09.html *Downloaded: 19.08.2024.)*

1 Cranford, Nathan, Turner, Jennifer: *The Human Body in Space.*

2 Johnson, Doug: *We don't know why, but being in space causes us to destroy our blood.*

using more favorable chest-back acceleration in the direction of the X-axis, instead of the traditional Gz overload in the head-foot direction, shifting blood from the head to the trunk and lower extremities.[3]

SPACE AS A HABITAT

The environmental effects of space are lethal to living organisms unless proper protection is applied. In a vacuum, there are a number of threats, the most obvious of which are oxygen and pressure deficits, but we must not forget extreme radiation and temperature fluctuations. Exposure to space can lead to hypoxia, decompression, and other diseases like hypocapnia. The effect of hypobaria (during decompression) might be hypocapnia (decreased pCO_2) but onboard the ISS, the main threat is hypercapnia (elevated CO_2 level) due to the exhaled air pockets without convection and less effective CO_2 absorption. There is about a 10-fold increase in ambient CO_2 levels, which might be a significant cause for SANS (Space-Associated Neuro-ocular Syndrome, involving headache, blurred vision, and decreased visual acuity). The top of these symptoms is experiencing cell mutation and deformation due to high-intensity photon impacts, which pose a constant threat to those in space.[4]

RADIATION

Radiation is nothing more than the propagation of particles in space or materials in the form of SPE (Solar Particle Events) and cosmic radiation. Radiation is one of the most dangerous effects humans can face during space travel. It poses a threat at the cellular level, as it can significantly affect the structure of DNA (deoxyribonucleic acid), thus deforming and destroying cells. There are acute symptoms, which can be classified as mild, from which recovery is almost guaranteed: diarrhea, some changes in the blood, and vomiting. These symptoms are not expected to occur if the astronaut is exposed to normal radiation, but if a solar flare were to occur while in space, much more serious problems would be expected due to the high levels of radiation. When confronted with this eventuality, astronauts on the International Space Station currently orbiting overhead will implement a pre-rehearsed and safe protocol to regroup in a shelter that offers the greatest protection against radiation and wait for the danger to end. The primary concern about space radiation is its long-term impact on astronauts. The long-term effects may include cataracts, increased cancer risk, and infertility. Certain health effects can skip a generation and may mutate through mutated genes in the descendants of the exposed person. The development of po-

3 Forster, Estrella M.: *A database to evaluate acceleration (+gz) induced loss of consciousness (g-loc) in the human centrifuge.*

4 Pilmanis, Andrew A., Sears, William J.: *Physiological hazards of flight at high altitude.*

tential health problems is influenced by the level of exposure, the sensitivity of the astronaut to the adverse health effects of radiation, and various other factors. These other factors include the altitude of the spacecraft above the Earth, the length of the mission, the protection of the spacecraft, the type of radiation, and the conditions of exposure.

The human body, as an object exposed to radiation, also has parameters that influence the extent of damage. These key parameters include age and gender, as well as overall health, which is closely monitored in astronauts to ensure they are free of any issues.[5] NASA experts have pointed out that a possible mission to Mars could result in a particularly high radiation load during the journey, based on measurements from a probe sent there in 2011.[6] If the first mission arrives on the surface of Mars in the future, they will not be able to fully relax there either, as the radiation measured on the planet is massive, often twice the normal level.[7] Even long-term, low-energy levels of radiation can provoke DNA damage, possibly leading to carcinogenesis or fetal malformations without a real threshold. Based on the Radiation Assessment Detector measurements of NASA's Curiosity rover during its transit to Mars, the astronauts would be exposed to a minimum of 660 ± 120 millisieverts during a full mission. NASA's career exposure limit set for astronauts is around 1000 millisieverts (as analog to nuclear industrial plant workers, maximizing the dose at 100 mSv for any 5 consecutive working years, aiming to keep it ALARA [as low as reasonably achievable]). Powerful ionizing radiation particles can target living tissues within the body throughout the mission, so presently the unpredictable radiation burden might be even showstopper from ethical aspects.[8]

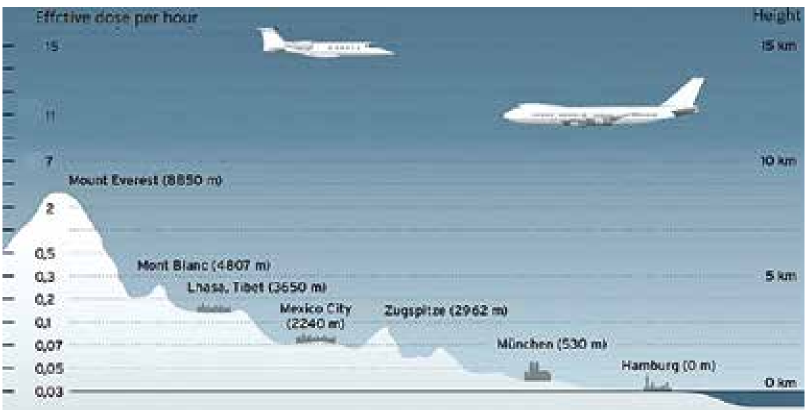

*Figure 2: Aircrews' radiation exposure (*https://www.bfs.de/SharedDocs/Bilder/BfS/EN/ion/radiation-protection/aircrews-radiation-expose.jpg?__blob=poster&v=2 *Downloaded: 10.09.2024.)*

5 Canadian Space Agency: *How does radiation affect the human body in space?*

6 Kerr, Richard A.: *Radiation Will Make Astronauts' Trip to Mars Even Riskier.*

7 Scott, Jim: *Large solar storm sparks global aurora and doubles radiation levels on the Martian surface.*

8 Townsend, Lawrence W.: *Implications of the space radiation environment for human exploration in deep space.*

VACUUM

Decompression sickness, which occurs as a result of exposure to a vacuum, develops when the human body experiences a rapid and drastic decrease in atmospheric pressure. Although gas exchange continues for a very limited time period in the vacuum of space, all gases, including oxygen, are eventually purged from the body. If the body does not receive enough oxygen beyond a certain point, the astronaut may lose consciousness and, in the worst-case scenario, their life. During decompression sickness, the nitrogen that is normally dissolved in the body tissues and blood comes out as a solution due to the sudden drop in pressure, forming bubbles throughout the body. These small bubbles can lead to various symptoms, including a feeling of numbness, aching joints, and even death if a person is exposed to a vacuum for at least 90 seconds. In practice, the process is more rapid. In 10 seconds, the subject would be unconscious. After 60 seconds, not only the nitrogen bubbles but also the evolving ebullism (vaporization of fluid water at body temperature) can demolish effective circulation due to the boiling effect.[9]

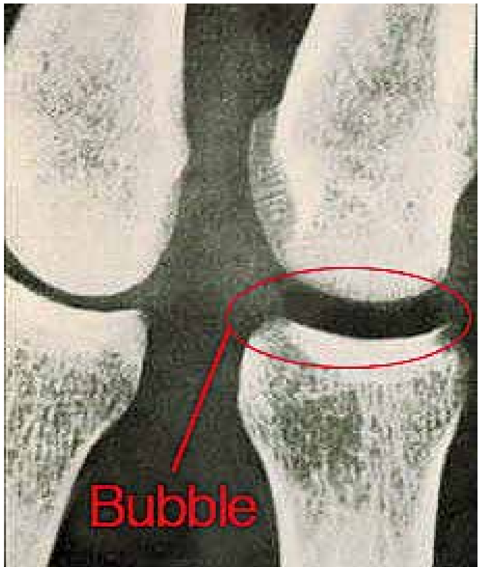

*Figure 3: Visible effect of peripheral decompression sickness (bends symptoms) (*https://www.asc-csa.gc.ca/eng/astronauts/space-medicine/decomp.asp *Downloaded: 19.08.2024.)*

Another present and unavoidable problem is hypoxia. We refer to this condition when there is not sufficient oxygen circulating in the blood, tissues, and cells to maintain normal bodily functions. Humans are not designed to exist at the altitudes where today's research takes place. The lungs lack the capacity and ability to function adequately in high-altitude, low-oxygen-density environments.[10] The main danger of hypoxia lies not only in the obvious functional problems but also in the fact that people generally do not feel or notice the onset of the condition. As a result, the decline in cognitive and physical performance may go unnoticed for a time. One method of preventing hypoxia is to pressurize the aircraft cabin, artificially increasing air pressure. Another method is to increase the amount of oxygen inhaled, such as by using an oxygen-generating system, which may involve wearing an oxygen mask. Modern Russian and American space suits fully perform both functions, making the likelihood of any vacuum-related incident during spacewalks very low.[11]

9 Landis, Geoffrey A.: *Human Exposure to Vacuum.*
10 Balog László et al.: *Bevezetés a sportdiagnosztikába.*
11 Southern Wings: *Hypoxia in aviation.*

TEMPERATURE

The temperature in space is either extremely high or extremely low for the human body to withstand. During a spacewalk, astronauts are exposed to a temperature fluctuation of 240 degrees Celsius. When they are on the sunlit side of the Earth, the temperature is +120 degrees Celsius, while on the shaded side, it drops to an equally extreme –120 degrees Celsius.[12] In space, heat loss occurs through radiation, as there is no suitable medium for heat conduction. Of course, astronauts venture into the harsh environment of space wearing appropriate suits, so there is no risk of freezing. The other factor is the unfiltered, direct sunlight to which a person could fall victim, as it causes significant heating of various surfaces. Additionally, ultraviolet radiation can inflict serious harm on a person in this hostile environment. Based on the experiences of past missions, specialists and engineers have developed the essential tool for staying in space: the spacesuit. This suit can be seen as a miniature spacecraft, as it performs the same vital function—keeping a person alive. Among its features, the spacesuit effectively handles extreme temperature fluctuations thanks to its multi-layered material. Additionally, a special liquid cooling system ensures a comfortable temperature for the astronaut inside the suit.

ZERO GRAVITY

We experience the sensation of weightlessness when gravity has little or no effect on our bodies. In practice, according to the laws of physics, gravity exists everywhere, as it is the force that keeps celestial bodies in their orbits. However, in Earth's orbit, a person does not perceive this force at all.[13] This sensation is similar to what we experience on a roller coaster during a sudden change in direction in an amusement park.

In fact, it is not just the feeling that is the same; it is also the underlying factor that causes it. The International Space Station, for instance, is in a constant state of freefall around the Earth. However, its forward velocity perfectly matches the rate of its fall toward the planet, resulting in the astronauts inside not being pulled in any specific direction. As a result, they float. At first glance, this might sound quite comfortable, but in reality, this condition leads to numerous health issues. The most discussed are bone density and muscle loss, but many other problems also arise during a long-term mission. One of the primary missions of the ISS, for example, is to study these effects so that, armed with valuable data, we can embark on future long-term and distant missions more safely as we continue our explorations beyond Earth.

We are well-adapted to Earth's surface conditions, so in response to weightlessness, various physiological systems start to change and, in some cases, deteriorate. While most of these changes are

12 NASA: *Spacewalk Spacesuit Basics.*

13 Howell, Elizabeth: *Weightlessness and its effect on astronauts.*

Figure 4: Floating in weightlessness
*(*https://phys.org/news/2016-10-flight-gravity.html *Downloaded: 10.08.2024.)*

temporary, some can have lasting effects on human health. After a certain period of time, these effects impact astronauts' performance and lead to a decrease in their ability to work. This happens as the risk of injury increases, the circulatory system weakens, and oxygen intake deteriorates.[14] Since 65–72% of our body is made up of fluids (more variation in organ level), gravity tends to force them into the lower regions. However, humans have perfectly adapted to this and are able to compensate for this phenomenon. If we disrupt this fluid flow by eliminating gravity, we can induce an overall cephalad shift, leading to changes in the fluid content of the inner ear, as well as issues with vision, taste, and smell.[15]

SPACE SICKNESS AND SPACE ADAPTATION SYNDROME (SAS)

The very first and most common symptom that astronauts notice during the initial period of weightlessness is SAS (space adaptation syndrome), as well as space motion sickness. It is the reverse of terrestrial motion sickness, arising when the environment and the individual seem to be moving relative to each other visually, even though the vestibular system does not provide a matching

14 NASA Glenn Research Center: *Exercise Physiology and Countermeasures Project (ExPC): Keeping Astronauts Healthy in Reduced Gravity.*

15 Shamei, Arian et al.: *Postural adaptation to microgravity underlies fine motor impairment in astronauts' speech.*

sensation of bodily movement. Symptoms of space sickness include nausea, vomiting, dizziness, headaches, fatigue, and general discomfort. The first incident of space adaptation syndrome was reported by astronaut Gherman Titov in 1961.[16] Space motion sickness is slightly different, lasting for 4 days and affecting even 60–70% of astronauts (in the Apollo program as well). Space adaptation syndrome comprises mainly the cephalad shift-induced cardiovascular alteration, with less effective blood volume and "puffy head, birdy legs" shape. Spaceflight Associated Neuro-ocular Syndrome (SANS) is also a recognized effect, which can generate eye and brain changes during long-duration spaceflight. The long-term health effects are uncertain, but they are being actively monitored and studied. In weightlessness, blood and cerebrospinal fluid shift toward the head, which is thought to be the root cause of structural changes in the eyes and brain. Long-duration astronauts may experience some or all of these changes, with individual biological differences. These vision changes can affect an astronaut's performance during flight, and the longer they remain in space, the more they may be affected. While many astronauts experience these effects only during their time in space, some changes may be permanent. Researchers are exploring solutions, including fluid shift countermeasures, to prevent SANS and to assess any long-term health effects.[17]

SPACEFLIGHT SARCOPENIA AND OSTEOPENIA

A significant consequence of long-term weightlessness is the loss of bone and muscle mass. In zero gravity, astronauts exert little to no pressure on the back or leg muscles used for standing, causing these muscles to weaken and shrink over time. As a result, some muscles deteriorate quickly, and without regular exercise, astronauts can lose up to 20% of their muscle mass within just 5 to 11 days. The muscle fiber composition also changes, with slow-twitch endurance fibers, essential for maintaining posture, being replaced by fast-twitch fibers, which are inadequate for heavy labor. Advances in research on exercise, hormone supplements, and medication may help preserve muscle and body mass. The functional inactivity of "antigravitational muscles" results in muscle atrophy, up to 50% muscle mass loss, and a decrease in muscle strength. The muscular atrophy seen in astronauts is very similar to deconditioned bed-rest patients, and upon return to Earth, some astronauts experience difficulty simply maintaining an upright posture with muscle soreness and tightness. Major postflight impairments require a proper rehabilitation program after returning to 1G gravity on Earth: the full recovery of muscle mass and strength can exceed 2 months.[18] [19] Bone metabolism also changes in the absence of gravity.

16 Delft University of Technology: *Why do astronauts suffer from space sickness?*
17 Fong, Kevin: *Moon landing: space medicine and the legacy of Project Apollo.*
18 Payne, Michael-Williams et al.: *Space Flight Rehabilitation*
19 Springel, Mark: *The human body in space: Distinguishing fact from fiction.*

In a typical Earth environment, calcium is deposited, and bone is built where the skeleton experiences stress. However, in a microgravity environment, where there is no such stress, bone metabolism significantly decreases.

Astronauts on Mir experienced an average bone loss of 1–2% per month. By comparison, the elderly typically lose 1–1.5% of bone mass annually, while postmenopausal women experience a loss of 2–3% per year.[20] The degree of bone loss is so dramatic that the risk of fractures is significantly increased, and symptoms similar to osteoporosis can be observed. In Earth's gravity, bones continuously regenerate through an advanced system that involves signals from specialized bone-building cells, known as osteoblasts and bone-degrading osteoclasts. These systems are interconnected, ensuring that whenever bone is broken down, new layers are formed to replace it—both processes occur together in a healthy adult. However, in space, microgravity leads to increased osteoclast activity. This becomes problematic because osteoclasts break down bones into minerals that are then reabsorbed by the body. These two cells do not respond properly to each other's presence, preventing bone formation. As a result, bone loss continues without regeneration. The abnormal behavior of these specialized cells was observed around the pelvic bones, as this area typically bears the most weight. Studies on mice have shown that just 16 days without gravity are enough to cause bone degeneration. Increased blood calcium levels from bone loss can lead to hazardous calcification of soft tissues and the possible formation of kidney stones. It is still unclear whether full bone regeneration occurs after returning to Earth. Observations of astronauts have shown that after spending 3–4 months in zero gravity, it takes approximately 2–3 years to regain nearly full bone density.[21] To prevent and minimize the effects of this undesirable phenomenon, the International Space Station is equipped with several tools. They have installed two specialized treadmills, to which astronauts are secured with elastic bands, a stationary exercise bike, and weight machines that use springs to achieve the desired effect.

Figure 5: Load-bearing treadmill exercise with gravity-simulated resistive straps (https://www.newscientist.com/article/dn11538-even-in-space-running-a-marathon-is-an-uphill-battle/ *Downloaded: 17.08.2024.)*

20 Hullander, Doug, Barry, Patrick L.: *Space Bones.*

21 Rodan, Gideon A.: *Bone homeostasis.*

Astronauts are required to exercise for at least 2 hours daily to minimize muscle loss. During long-term missions, astronauts wear compression trousers to help reduce the process of bone loss. Compression trousers mainly prevent fluid shift to the lower body in the reentry phase, minimizing orthostatic tolerance. Suits with resistive straps or GLCS (Gravity Loading Countermeasure Skin) suits apply Earth-like loading to help maintain bone mass.[22] We can also help reduce bone thinning through our diet by increasing calcium and vitamin D intake, which is controversial, regarding kidney stone risks. Various drug treatments currently used or proposed for osteoporosis, such as hormone therapy (estrogen or progestin), selective estrogen receptor modulators, bisphosphonates, teriparatides, and human parathyroid hormone are also powerful osteoanabolic agents. However, it is not yet known if they will offer the same benefits in space as they do for osteoporosis. Currently, space agencies are also deploying advanced computational systems to understand how muscle atrophy can be reduced in the state of weightlessness.[23]

FLUIDS (SPACE ADAPTATION SYNDROME)

In space, people experience continuous fluid loss, leading to a potential 22% reduction in blood volume. This effect becomes evident upon returning to Earth, where the decreased blood volume can cause problems, such as severe dizziness, while standing. The phenomenon occurs because Earth's gravity pulls fluids, including blood, toward the legs.[24] Consequently, the already diminished blood volume is further directed to the lower extremities, rather than being adequately distributed to the head. When gravity ceases, the hydrostatic pressure throughout the body also disappears. The resulting changes in blood distribution

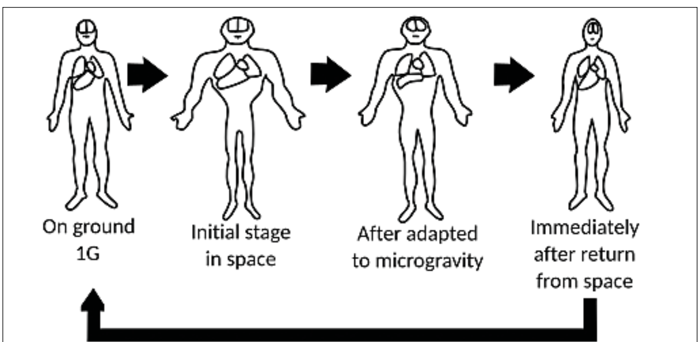

Figure 6: Fluid flow stages in microgravity (https://commons.wikimedia.org/wiki/File:Space_body_fluid.svg *Downloaded: 18.08.2024.)*

22 Waldie, James: *Astronaut Compression Skinsuits.*

23 Cavanagh, Peter R. et al.: *Exercise and pharmacological countermeasures for bone loss during long-duration space flight.*

24 Shibata, Shigeki et al.: *Impact of Prolonged Spaceflight on Orthostatic Tolerance During Ambulation and Blood Pressure Profiles in Astronauts.*

are similar to those that occur when a person transitions from a standing to a lying position.

A persistent redistribution of blood volume leads to facial edema, puffy head, birdy legs, and other undesirable side effects. Upon returning to Earth, the reduced blood volume may cause orthostatic hypotension, leading to circulatory insufficiency in the brain due to the sudden drop in blood pressure. Fluid-loading measures and salt re-supplement are applied by astronauts before landing and have significantly improved orthostatic tolerance after spaceflight. Both the quality and quantity of electrolytes critically affect how water is absorbed and distributed within the body.[25]

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AZ ŰRMISSZIÓK EMBERRE GYAKOROLT HATÁSA 1.

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Kulcsszavak emberi test, űrrepülés, súlytalanság, hosszú távú hatás, izom, sugárzás, Artemis-program

Absztrakt *Jurij Gagarin első emberes űrrepülésétől kezdve, továbbá a soron következő valamennyi küldetés során hangsúlyt fektettek a tudósok az emberi test működésének és változásainak vizsgálatára, az űrrepülés teljes spektrumán. Az űrutazás hatással van az egész testre, és kivétel nélkül befolyásolja minden egyes szervünket, illetve a pszichénket. Abban a pillanatban, ahogy a súlytalanság hatásának vagyunk kitéve, és a Föld gravitációja megszűnik, olyan változásokat tapasztalhatunk, mint például az oszteoporózis (az űrrepülés okozta csontritkulás), a vörösvérsejtek számának csökkenése (űranémia), valamint különféle, a küldetések során megfigyelt rendhagyó tünetek. Sokan nincsenek tisztában azzal, hogy az űrprogramok előnyei szinte minden embert érintenek a Földön, számos találmány és felfedezés kizárólag az űrprogramoknak köszönhetően jöhetett létre.*

Potential Health Risks for FPV Drone Operators

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Keywords FPV drone, operator, health risk, VR, battlefield

Abstract *FPV (first-person view) drones have quickly become essential assets in modern warfare, particularly due to their use in the ongoing Russia-Ukraine conflict. Their ability to deliver precise strikes and provide immediate situational awareness has significantly transformed battlefield dynamics. As the deployment of FPV drones continues to rise, it becomes imperative to address the potential health risks associated with prolonged and intense drone control. Issues such as visual strain, cognitive overload, and musculoskeletal problems pose particular challenges during extended operations. In response to the growing role of FPV drone technology in national defence strategies, this article seeks to bring to light the health risks faced by FPV drone operators. When considering the introduction of a potential FPV drone operator training program, it is important to not only establish the technical conditions but also implement preventive health measures to ensure the operational readiness and long-term well-being of the personnel.*

INTRODUCTION

FPV drones, initially developed for recreational and commercial use, have quickly evolved into powerful tools across various fields, including agriculture, search and rescue, surveillance, and more recently, military operations. Compared to UAVs (Unmanned Aerial Vehicles) commonly used so far, these drones differ in size and strikeability. Their versatility, cost-efficiency, and ability to provide real-time, immersive visual feedback have made them indispensable in high-stakes environments such as warfare, where precision and rapid decision-making are critical. The most dramatic example of their military application has emerged in the Russia-Ukraine conflict, where FPV drones have been used extensively for reconnaissance and tactical strikes. As shown in Figure 1, these drones are equipped with an advanced camera and video transmitter to enable the operator to see from the perspective of the drone via VR goggles. The rotors are controlled by the signal emitted by the operator's remote control and received by the remote-control receiver on the drone. This bidirectional low-latency communication allows the operators to navigate complex terrains and engage targets with unprecedented accuracy, all while remaining far from the physical battlefield.

However, the rapid expansion of FPV drone usage raises important concerns regarding the long-term health impacts on operators, particularly in high-pressure

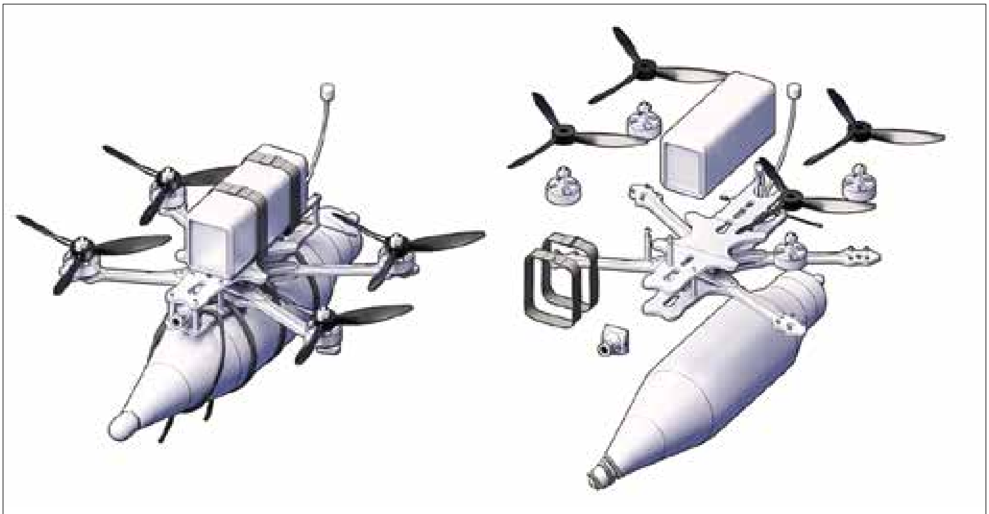

Figure 1: FPV drone components
*(*https://www.ecssr.ae/en/research-products/reports/2/198140 *Downloaded: 21.10.2024.)*

Figure 2: Drone pilot in operation with his squad
*(*https://www.atlanticcouncil.org/blogs/ukrainealert/fpv-drones-in-ukraine-are-changing-modern-warfare/ *Downloaded: 14.10.2024.)*

environments such as the military. Studies have shown that FPV drone operators are vulnerable to both physical and mental health risks, including visual strain, cognitive overload, and psychological distress. For example, research has identified a significant presence of mental health disorders, such as PTSD, among remotely piloted aircraft (RPA) operators, despite their physical distance from the battlefield. Furthermore, pilots have reported experiencing distress and trauma from viewing live combat through their drone cameras, leading to a need for better mental health support systems in both military and civilian contexts.

In addition to psychological risks, the physical demands of drone piloting, such as maintaining posture for extended periods and repetitive hand movements, pose significant ergonomic challenges. Studies have highlighted the importance of physical fitness in mitigating these risks, particularly in military settings where high performance is critical during prolonged missions.[1] As FPV drones continue to integrate into both military and civilian domains, understanding the full scope of these health risks is crucial for developing guidelines and preventive measures to protect operators from long-term harm. Consequently, this paper aims to explore the physical and mental health risks associated with FPV drone piloting, focusing on the unique demands posed by this emerging technology in modern warfare and beyond. These can help optimize the operator selection process, as the currently applied guidelines are typically based on the deployment of operational-level UAVs. The NATO STANAG 7192 AAMedP-1.25 can be taken as a reference for this process.[2] In contrast, FPV drones are used at the tactical level, therefore, other parameters may need to be considered.

PHYSICAL HEALTH ISSUES

Operating FPV drones, especially in demanding military environments, exposes operators to a variety of physical health risks due to the sustained focus, posture, and fine motor control required. The extended use of FPV goggles, along with intense hand-eye coordination tasks, puts a significant strain on multiple aspects of physical well-being.

Visual strain (Computer Vision Syndrome)

FPV drone pilots rely heavily on FPV goggles or screens, focusing intently on real-time video feeds for extended periods. This intense visual demand can result in digital eye strain, also known as Computer Vision Syndrome (CVS), which manifests as blurred vision, dry or irritated eyes, and head-

1 Galashevskyi, Hennadiy: *The importance of physical fitness of FPV drone operators in the process of performing combat tasks as intended*, 89.

2 Szabó, Sándor András, Hornyik, József: *UAV (pilóta nélküli légijárművek) műveletek repülőegészségügyi feltételrendszerének biztosítása*, 66.

aches. Studies suggest that prolonged exposure to digital screens can lead to exacerbated visual fatigue, especially in fast-moving tactical environments where constant refocusing is required. In military settings, pilots often work under challenging lighting conditions, such as low-light or high-glare environments, which further intensify these issues.[3]

Blue light exposure

FPV goggles and screens emit significant amounts of blue light, which has been linked to both short- and long-term eye problems. Short-term exposure contributes to eye fatigue and discomfort, while long-term exposure has been associated with an increased risk of macular degeneration and disrupted circadian rhythms. This disruption of sleep cycles is particularly concerning for military drone operators who are often required to conduct night missions, which can lead to fatigue and diminished alertness in subsequent operations.[4]

Neck and upper back pain

Wearing FPV goggles requires pilots to maintain a consistent posture, often with the head slightly forward, which can cause strain on the cervical spine and upper back muscles. Prolonged drone piloting sessions, particularly without proper posture or ergonomic support, are likely to result in chronic neck pain and tension. This static, hunched-over position is associated with musculoskeletal issues, such as "tech neck" and cervical muscle strain, which can impair a pilot's comfort and focus during missions.[5]

Repetitive strain injuries (RSIs)

The precise and repetitive movements required to control drones using joysticks or handheld controllers can lead to repetitive strain injuries (RSIs) in the hands, wrists, and fingers. Over time, this can develop into conditions like carpal tunnel syndrome, tendinitis, or trigger finger. In high-stakes military operations where precision and quick reflexes are essential, the cumulative strain on joints and muscles can lead to performance degradation and chronic pain.[6]

3 Rosenfield, Mark: *Computer vision syndrome: a review of ocular causes and potential treatments.*

4 Ouyang, Xinli et al.: *Mechanisms of blue light-induced eye hazard and protective measures: a review.*

5 Galashevskyi, Hennadiy: *The importance of physical fitness of FPV drone operators in the process of performing combat tasks as intended,* 89.

6 Northey, G. W.: *The effects of stiffness and speed on upper limb electromyography during joystick use*, 4-8.

Hand and thumb strain ("Gamer's Thumb")

FPV drone controllers often rely heavily on thumb movements to operate joysticks or control switches. This repetitive thumb motion can lead to a condition known as de Quervain's tenosynovitis, or "Gamer's Thumb", where the tendons in the thumb become inflamed due to overuse. In military contexts, where swift and precise control is crucial, the risk of hand and thumb injuries is heightened, which can limit a pilot's ability to maintain prolonged control or react quickly in critical situations.

Lower back pain and posture-related issues

Pilots operating FPV drones from seated positions for extended periods can develop poor posture, leading to lower back pain and stiffness. Inadequate seating, lack of lumbar support, and static postures can contribute to musculoskeletal imbalances, potentially resulting in chronic conditions such as herniated discs or sciatica. Given that military operators may be required to remain seated for long hours in confined spaces, the risk of lower back issues is notably increased.[7]

Hand-eye coordination fatigue

Constant reliance on fine motor skills and hand-eye coordination during FPV drone piloting can lead to fatigue in both the visual and motor systems. Pilots must synchronize hand movements with real-time video feedback, requiring intense concentration and precision. Over extended missions, this strain can lead to a decline in motor accuracy and slower reaction times, ultimately affecting mission success in high-pressure situations.[8]

Immersive disorientation (post-flight disconnection)

After extended periods of viewing the battlefield through FPV goggles, some operators may experience disorientation or difficulty reorienting themselves to their physical surroundings upon removing the headset. This condition, known as immersive disorientation, can result in dizziness or imbalance similar to post-flight vertigo, which may impair the pilot's physical or mental capabilities following prolonged missions.[9]

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7 Galashevskyi, Hennadiy: *The importance of physical fitness of FPV drone operators in the process of performing combat tasks as intended,* 89.

8 Ge, X. et al.: *Influence of Head up Display on Visual Fatigue and Eye-Hand Discoordination in Runway Incursion Scenarios*, 44.

9 Souchet, A.D. et al.: *A narrative review of immersive virtual reality's ergonomics and risks at the workplace: cybersickness, visual fatigue, muscular fatigue, acute stress, and mental overload*, 21.

MENTAL HEALTH ISSUES

Beyond physical health challenges, FPV drone pilots are also vulnerable to a range of mental health issues due to the unique demands and stressors associated with operating in high-pressure environments. While physically distant from the battlefield, pilots face intense psychological challenges similar to those experienced by traditional combat personnel. Therefore, there is no relevant difference between drone operators and manned aircraft pilots, in relation to mental health issues.[10]

Cognitive overload

FPV drone piloting requires high levels of concentration and multitasking, as pilots must simultaneously control the drone, analyze real-time video feeds, and react to rapidly changing environments. The cognitive demand is exacerbated in military operations, where pilots are often required to make split-second decisions under extreme pressure. Studies indicate that such cognitive overload can lead to mental fatigue, reduced situational awareness, and slower reaction times, particularly during extended operations. Over time, this can impair decision-making and mission effectiveness, contributing to mental burnout.[11]

Simulator (VR) sickness

FPV drones immerse the pilot in a virtual environment through VR goggles, creating a disconnection between visual input and physical sensations. This sensory mismatch often leads to symptoms similar to motion sickness, such as nausea, dizziness, headaches, and disorientation, collectively referred to as "simulator sickness" or "cybersickness". Prolonged exposure to these environments can exacerbate symptoms, making it difficult for pilots to operate effectively, particularly in fast-paced, high-stakes tactical scenarios.[12]

Stress and anxiety

The high-stakes nature of military drone operations, including reconnaissance and strike missions, inherently generates significant stress. Pilots are responsible for critical tasks in hostile environments, where the risk of mission failure, equipment loss, or civilian casualties is ever-present. This heightened psychological pressure often leads to chronic stress and anxiety, which can have long-term

10 Otto, Jean L., Webber, Bryant J.: *Mental health diagnoses and counseling among pilots of remotely piloted aircraft in the United States Air Force*, 7.

11 Souchet, A.D. et al.: *A narrative review of immersive virtual reality's ergonomics and risks at the workplace: cybersickness, visual fatigue, muscular fatigue, acute stress, and mental overload*, 32.

12 Souchet, A.D. et al.: *A narrative review of immersive virtual reality's ergonomics and risks at the workplace: cybersickness, visual fatigue, muscular fatigue, acute stress, and mental overload*, 35–36.

negative impacts on both mental and physical health. Research shows that such stressors are comparable to those experienced by traditional combat pilots, despite the physical distance of drone pilots from the battlefield.[13]

Isolation and fatigue

Drone piloting often requires long hours of focused work in isolated environments, such as small, enclosed rooms or remote locations. The solitary nature of these tasks, coupled with the high concentration required, can lead to feelings of isolation and loneliness. Over time, this isolation may result in mental and emotional exhaustion, increasing the likelihood of burnout. Furthermore, the cumulative fatigue associated with prolonged focus can reduce operational performance, leading to slower reaction times and decision-making errors. Besides all that, ultra-long missions can also lead to circadian rhythm disruptions and sleep disorders.[14]

Decision fatigue

FPV drone operators are frequently required to make rapid, high-stakes decisions under pressure, particularly in combat scenarios. The constant need for precision and speed can lead to decision fatigue, where a pilot's ability to make effective choices deteriorates over time. This degradation in decision-making capacity can increase the risk of operational mistakes, particularly in prolonged missions where the mental strain is heightened.[15]

Post-traumatic stress disorder (PTSD)

Although FPV drone pilots are physically removed from the battlefield, they may still experience psychological trauma due to their role in combat operations. Research has shown that pilots involved in surveillance or strike missions may witness distressing events through the drone's live feed, leading to the development of PTSD symptoms similar to those experienced by ground-based combat personnel. Repeated exposure to traumatic imagery or the stress of making life-or-death decisions can contribute to emotional numbness, intrusive memories, and heightened anxiety.[16]

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13 Otto, Jean L., Webber, Bryant J.: *Mental health diagnoses and counseling among pilots of remotely piloted aircraft in the United States Air Force*, 3.

14 Werner, Andreas et al.: *The New Quality of Aviation Unmanned Aerial Vehicles (UAV) Prevent Psychological Stress of Military Drone Operators*, 27.

15 Rahmani, Hoda, Weckman, Gary R.: *Working under the Shadow of Drones: Investigating Occupational Safety Hazards among Commercial Drone Pilots*, 60.

16 Lowe, Matthew, Gire, James T.: *In the mind of the predator: the possibility of psychological distress in the drone pilot community.*

Burnout

The combination of high-pressure environments, cognitive overload, isolation, and prolonged stress can lead to burnout among FPV drone pilots. Burnout not only affects mental health but also reduces operational performance by impairing a pilot's ability to concentrate and make sound decisions during missions. Studies indicate that the risk of burnout is particularly high among military drone operators engaged in repeated high-stakes operations without adequate rest or mental health support.[17]

CONCLUSION

FPV drones have rapidly transformed modern warfare, offering unprecedented advantages in battlefield intelligence, precision strikes, and situational awareness, as seen in the ongoing Russia-Ukraine conflict. Both sides have embraced these drones, recognizing their tactical value. However, the growing reliance on FPV drones introduces a range of physical and mental health risks to pilots, stemming from the unique demands of operating these systems through immersive FPV goggles and handheld controllers. The physical challenges, such as visual strain, repetitive motion injuries, and posture-related issues, alongside mental health risks, like cognitive overload, stress, and simulator sickness, present significant concerns for the long-term well-being of FPV drone operators. As military forces consider incorporating FPV drones into national defence strategies and potentially establishing dedicated FPV drone training programs, it is essential to acknowledge these health risks. Ensuring the physical and mental health of FPV drone operators is critical to maintaining operational effectiveness and the overall readiness of military personnel. Careful attention must be paid to designing training programs that incorporate health monitoring, preventive measures, and support systems to mitigate the risks. Only by prioritizing the well-being of drone operators can we fully harness the tactical potential of FPV drones while safeguarding the health and performance of those who control them. It is important to keep in mind that the poor physical and mental preparedness of operators increases the risk of accidents, which can result not only in financial loss but also in endangering civilians.

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17 Saini, Rajiv Kumar et al.: *Cry in the sky: Psychological impact on drone operators*, 17.

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AZ FPV-DRÓNOPERÁTOROKAT ÉRINTŐ LEHETSÉGES EGÉSZSÉGÜGYI KOCKÁZATOK

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Kulcsszavak FPV-drón, pilóta, egészségügyi kockázat, VR, harctér

Absztrakt *Az FPV (belső látképes) drónok gyorsan a modern hadviselés kulcsfontosságú eszközeivé váltak, különösen a jelenleg is zajló orosz–ukrán konfliktusban való alkalmazásuk révén. A pontos csapások és a közvetlen helyzetfelismerés nyújtotta lehetőségek révén jelentősen átalakították a harctéri dinamikát. Az FPV-drónok bevetési*

száma folyamatosan emelkedik, ami alapot ad arra, hogy foglalkozzunk az elhúzódó és intenzív drónirányításból fakadó egészségügyi kockázatok kérdésével. Az olyan problémák, mint a szemfáradás, kognitív túlterhelés és mozgásszervi panaszok különösen a hosszan tartó műveletek során jelentenek kihívást. Válaszul az FPV-dróntechnológia nemzetvédelmi stratégiákban betöltött növekvő szerepére, ez a cikk az FPV-drónpilótákra leselkedő egészségügyi kockázatokat igyekszik napvilágra hozni. Egy lehetséges FPV-drónpilótaképzési program bevezetése kapcsán fontos figyelembe venni, hogy a technikai feltételek megteremtése mellett az egészségügyi megelőző intézkedések meghatározása is szükséges a személyzet operatív felkészültségének és hosszú távú egészségének biztosítása érdekében.

Work Fatigue in the Crosshairs

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Keywords work fatigue, force health protection, nutrition analysis, physical activity, sleep

Abstract *Examining work fatigue is vital for military organizations in order to maintain high levels of performance, occupational safety, and physical and mental health among military personnel. The aim of our research was to examine the consequences of the physical and mental stress associated with Camp Deployment Week (CDW) military training. According to the results of the nutrition analysis, the quality of the meals provided was inadequate, with too much fat and only fast-absorbing carbohydrates with a high glycaemic index. Regarding the micronutrients, the values of cholesterol, sodium, and phosphorus were particularly high. Regarding physical activity, the average number of steps was 118,000 steps/week, which is approximately 98 km/person/week. Based on the BMI value, 55% of the participants belonged to the overweight or obese category, and an elevated body fat percentage was measured in 65% of the participants. By the end of the training, we found a positive change in the body composition indicators of the soldiers with a high BMI. According to the Berlin questionnaire, 4 people are likely to suffer from sleep apnoea, 40% of the participants slept less than 7 hours a day and about 50% had inadequate sleep quality. The proportion of sleep disorders increased from the 3rd day of the training. The average heart function and cardiac stress values were appropriate (except for three and two people). According to our results, morning stress values were significantly lower as the sleep length increased. According to the score values of BDI-SF, it is probable that two people had moderate depression.*

INTRODUCTION

Work fatigue is a critical safety and well-being issue in military organizations. Numerous military research studies have focused on the effects and consequences of work fatigue within deployed combat settings, but less attention has been paid to non-combat, non-deployed conditions.[1 2 3] We believe that examining

1 Blais, Ann-Renée. et al.: *Work Fatigue Profiles: Nature, Implications, and Associations with Psychological Empowerment.*

2 Frone, Michael R., Blais, Ann-Renée: *Work Fatigue in a Non-Deployed Military Setting: Assessment, Prevalence, Predictors, and Outcomes.*

3 Weeks, Sharon R. et al.: *Physiological and Psychological Fatigue in Extreme Conditions: The Military Example.*

this topic in a non-combat, non-deployed context is vital for military organizations in order to maintain high levels of performance, occupational safety, and physical and mental health among military personnel. Therefore, the study was carried out during the training called "Camp Deployment Week" (CDW) among the soldiers of the HDF 205th Air Defence Regiment. CDW is a special training, the purpose of which is to maintain personal and unit readiness. Soldiers have to stay in the barracks all week long, where they take part in various training sessions from morning to evening. The aim of the research was to examine the consequences of the physical and mental stress associated with CDW military training. The advantages of the research:

- At the organizational level: The results and experiences obtained by examining the factors affecting the unit's adaptability and performance can be incorporated into the tasks related to the planning and implementation of training. It is possible to develop preventive interventions that allow soldiers to be healthy and fit, reach the maximum of their abilities, and are applicable at a specific time and place.
- At the individual level: Soldiers receive feedback on what physiological and mental consequences fatigue has on them and what they can do to maintain their health.

The investigation was based on a complex research plan consisting of two blocks: a psychological and a medical block. The research protocol includes nutrition analysis, physical activity and sleep monitoring, and subjective measurement of fatigue, depression, sleep apnoea and sleep length and quality. Furthermore, some instrumental examinations, such as cardiac function, stress load, body composition, and short-term memory are also included.

SAMPLE AND METHODS

A total of 76 people took part in the training, and a sample of 20 people was randomly selected from among them. The participants gave their written consent to participate and to the data being used for statistical purposes. The main socio-demographic characteristics of the sample can be found in Table 1.

Table 1. *The main socio-demographic characteristics of the sample*

Sample characteristics			
Number	20		
Gender (%)	Male: 90%		Female: 10%
Mean age	31.5 years (Min.: 19; Max.: 56)		
Sporting activity	7.4 h/week (Min.: 3; Max.: 14)		
Education	Elementary school: 5%	Secondary school: 75%	College or university: 20%

FEATURES OF THE DEVICES USED

Omron BF511

To measure body composition, we used OMRON BF 511. This type of body composition analyser has been standardized in the HDF since 2015. The device also measures body weight, the ratio of body fat to visceral fat, the percentage of skeletal muscle structure, and is also capable of evaluating BMI classification value and resting metabolic rate (RMR).

Cardioscan

To test cardiac function and heart stress value, we used Cardioscan, which digitizes the pulses delivered by the heart through 4 electrodes and converts the ECG trace to ECP on a connected PC or laptop. The shape and colour of the image show the state of the heart immediately and traceably. From the digitized ECG registry, Cardioscan analyses heart rate variability (HRV), which changes with the stress on the heart, and can be used to detect the individual heart stress factor. The ECG as a function of time and the pulse rate spectrum provide information on the extent of the psychological and physiological load on the heart. For the reference range of values measured and calculated by Cardioscan, see Table 2.

Table 2: *Reference range of values measured and calculated by Cardioscan*

	Good	Normal	Worrying	Critical
Cardiac function	5.0–4.1	4.0–3.0	2.9–1.0	<1.0
Cardiac stress	<17%	17–50%	51–90%	>90%

Garmin Vivoactive HR

We monitored physical activity and sleep with the Garmin Vivoactive HR watch. Using heart rate data, the watch provides information on the calories burned and quantifies the intensity of the fitness activities. Garmin Connect™ was used to track and analyse the data. Sleep statistics, including total hours of sleep and sleep movement (such as deep sleep, light sleep, and periods of being awake), are displayed in the Garmin Connect™ account.

Berlin questionnaire

The Berlin questionnaire (11 items) was used for identifying subjects with obstructive sleep apnoea. The questionnaire consists of 3 categories related to the risk of having sleep apnoea. Patients can be classified into High Risk or Low Risk based on their responses to the individual items and their overall scores in the symptom categories. It is a simple, self-administered patient questionnaire and a validated predictive assessment tool designed to assess three OSA risk categories.[4]

Three-Dimensional Work Fatigue Inventory (3D-WFI)

The 3D-WFI (18 items) measured the level of physical, mental, and emotional fatigue of the participants. It measures tiredness experienced during and at the end of the workday. Each item loaded highly on its respective factor, thereby discriminating between Physical Work Fatigue (6 items), Mental Work Fatigue (6 items), and Emotional Work Fatigue (6 items).[5]

Beck Depression Inventory Short Form (BDI-SF)

The BDI-SF (13 items) was used for screening depression and measuring its severity in the case of participants. It is a relevant psychometric instrument, showing high reliability and a capacity to discriminate between depressed and non-depressed subjects.[6 7]

The study started with a preparation phase we made the research plan and the nutritional analysis, which was based on the menu and the used raw materials. In addition, random sampling was carried out. Before the examination phase, the participants were informed about the study, consent forms and questionnaires were filled out, and body composition was measured. In the examination phase, instrumental tests and data collection from the smartwatch were carried out almost every day in the morning and evening hours.

We placed great emphasis on following the ethics rules in relation to data collection and analysis (informed consent form, analysis inadequate for personal identification), the results will be hereinafter communicated in compliance with the ethics rules.

RESULTS

In our lecture, we presented mainly descriptive statistical results, a deeper analysis is in progress, the results of which will be published later.

According to the results of smartwatch monitoring, 50% of the sample was in a caloric deficit during the training. The quality of the meals provided was inadequate, with too much fat and only fast-absorbing carbohydrates with a high glycemic index. There were very few vegetables on the menu and no fruit at all. Regarding the micronutrients, the values of cholesterol, sodium, and

4 Chamara, V. Senaratna et al.: *Validity of the Berlin questionnaire in detecting obstructive sleep apnea: A systematic review and meta-analysis.*

5 Frone, Michael R., Tidwell Marie-Cecile O.: *The meaning and measurement of work fatigue: Development and evaluation of the Three-Dimensional Work Fatigue Inventory (3D-WFI).*

6 Beck, A. T., Beck, R. W.: *Screening depressed patients in family practice. A rapid technic.*

7 Rózsa, S. et al.: *A Beck depresszió kérdőív rövidített változatának jellemzői hazai mintán.*

phosphorus were particularly high. In Table 3, the values marked in red show a deviation of at least 50% from the recommended amount.

Regarding physical activity, the average number of steps was 118,000 steps/week, which is approximately 98 km/person/week.

Based on the BMI value, 55% of the participants belonged to the overweight or obese category, and an elevated body fat percentage was measured in 65% of the participants.

By the end of the training, we found a positive change in the body composition indicators of the soldiers with a high BMI, their body fat percentage decreased, while their skeletal muscle percentage increased.

According to the results of the Berlin questionnaire, 4 people are likely to suffer from sleep apnoea. In assessing sleep, we used CDC recommendations as a basis, sleep was considered inadequate if it was shorter than 7 hours, and in terms of stages, if the proportion of deep sleep stages was less than 40%. According to the results of smartwatch monitoring, 40% of the participants slept less than 7 hours a day and about 50% had inadequate sleep quality. The proportion of sleep disorders increased from the 3rd day of the training.

Table 3: *Nutrition-related outcomes (micronutrients)*

	Needed value	Date				
		22.05.	23.05.	24.05.	25.05	26.05
Vit. B1 (μg)	900	3149	3957	3128	2108	2056
Vit. B2 (μg)	1300	1867	2376	2885	2030	1494
Vit. B6 (μg)	1300	4325	4549	4048	1808	4921
Vit. B12 (μg)	2.0	5.0	4.46	14	4.37	4.68
Vit. C (mg)	90	84	100	83	124	97
Retinol (mg)	0.8	0.4	1.2	5	0.47	0.45
Vit. E (mg)	15	27	55	27	37	35
Folic acid (μg)	200	151	118	410	196	129
Niacin (mg)	14	34	40	44	20	30
Panthotenic acid (mg)	5	5.1	3.9	10	5.2	3.6
Cholesterol (mg)	300	740	573	619	716	392
Fiber (mg)	25	28	38	40	24	34
Na (mg)	2000	10560	10277	9415	9485	9834
K (mg)	3500	3848	4563	3904	1948	4409
Ca (mg)	800	370	957	464	1206	402
P (mg)	620	1670	1947	1981	1699	1536
Mg (mg)	300	476	600	663	450	522
Fe (mg)	15	17	14.5	25	11	16
Zn (mg)	9	19	20	23	19	17
Cr (μg)	120	64	93	46	76	62

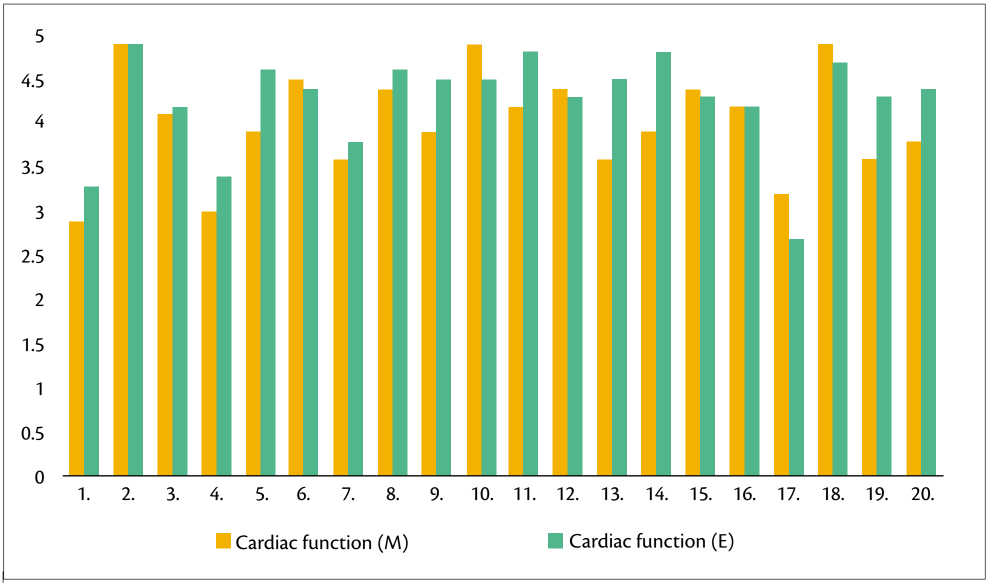

Figure 1: Average morning (M) and evening (E) cardiac function values

As for cardiac function, the average values ranged from 2.7 to 4.9. The average morning and evening heart function values were appropriate except for three people (No1, No4, and No17) (Figure 1).

When tested for cardiac stress, the average values ranged from 10% to 88%.

The average morning and evening cardiac stress values were appropriate except for two people (No4 and No17) (Figure 2).

We would like to point out that although these values are appropriate, they cannot be considered as good, especially if we consider the young average

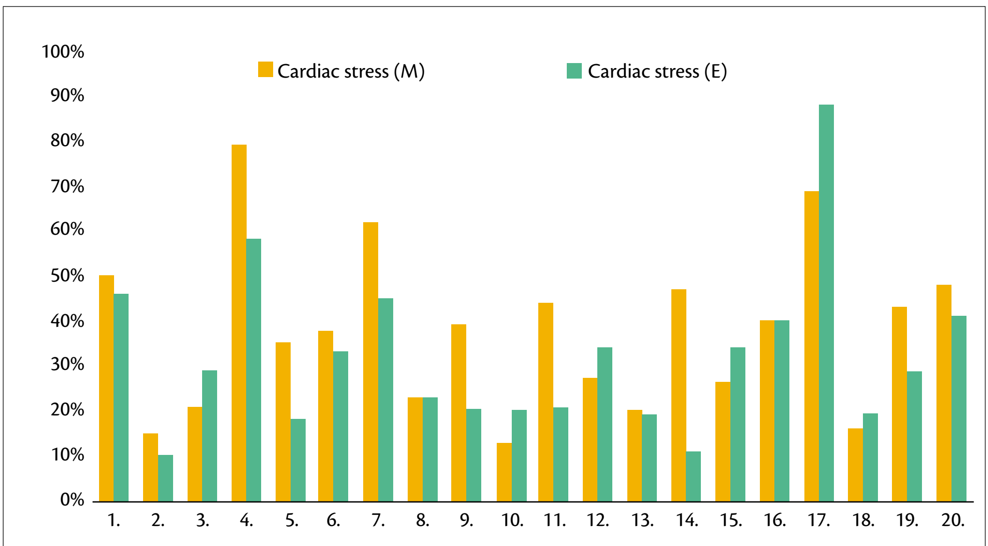

Figure 2: Average morning (M) and evening (E) cardiac stress values

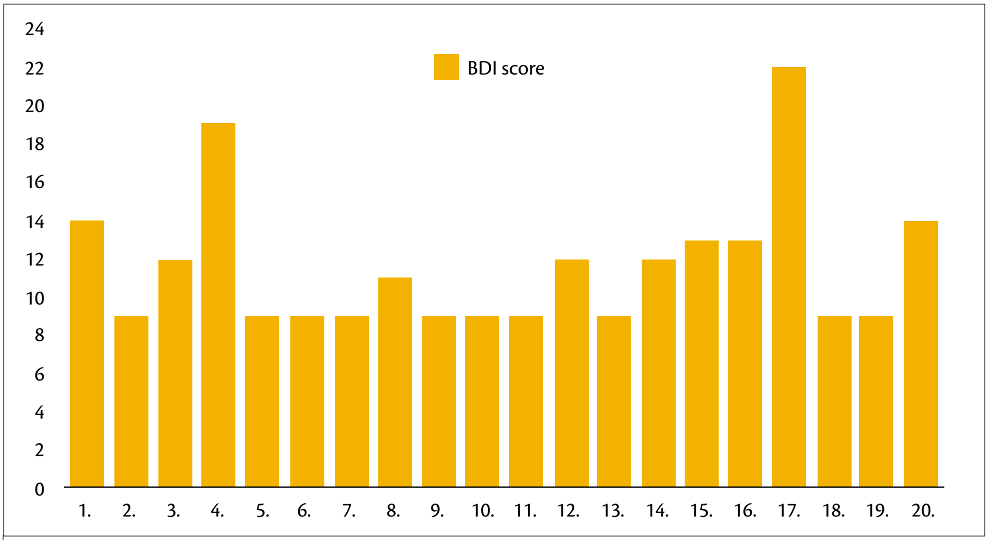

Figure 3: Score values of the Beck depression scale

age of the sample. This is especially true for cardiac stress values. Unfavourable values can also be caused by increased physical activity, but in our opinion, these results require further investigation.

A linear regression analysis was performed to analyse the relationship between sleep length and morning cardiac stress value. According to our results, morning stress values were significantly lower as the sleep length increased.

According to the score values of BDI-SF, it is probable that No4 and No17 had moderate depression (Figure 3).

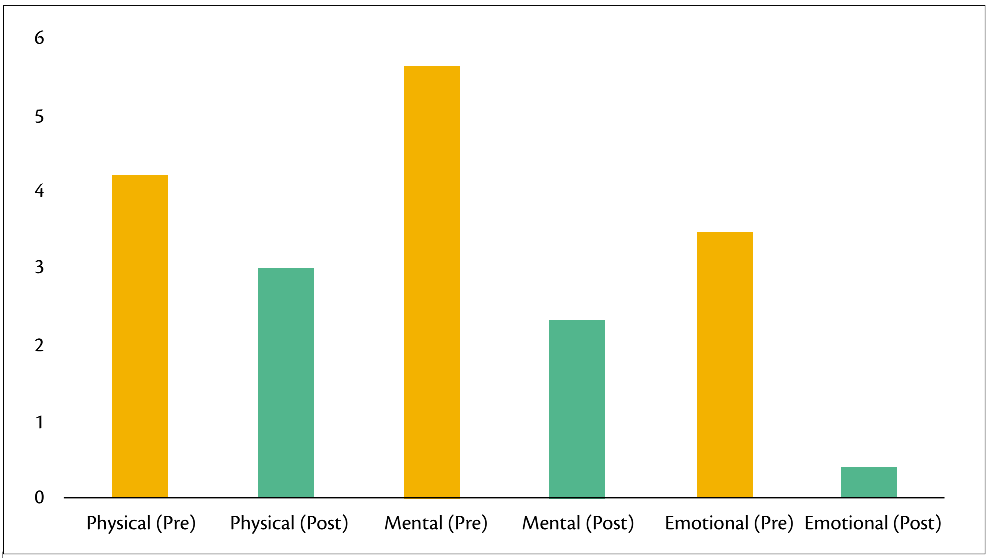

Figure 4: Average scores of the physical, mental, and emotional fatigue scales of the 3D-WFI

The average scores of the physical, mental, and emotional fatigue scales of the 3D-WFI can be seen in Figure 4.

We detected a significant decrease in the mental (t=2.58; df=14; p=0.021) and emotional (t=2.45; df=14; p=0.027) fatigue scores at the end of the training. It may seem a surprising result, but it agrees with what soldiers say after returning from deployment. This result draws attention to the importance of routine and everyday work stressors. The lower scores measured at the end of the training may be due to the fact that during the training the tasks and responsibilities are clearer, the tasks are more predictable, and the work is more plannable than on a routine workday.

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CÉLKERESZTBEN A MUNKAFÁRADTSÁG

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Kulcsszavak munkafáradtság, egészségügyi haderővédelem, táplálkozáselemzés, fizikai aktivitás, alvás

Absztrakt *A munkafáradtság vizsgálata létfontosságú a katonai szervezetek számára a katonaállomány magas szintű teljesítményének, munkabiztonságának és testi-lelki*

egészségének megőrzése érdekében. Kutatásunk célja a Tábori Kihelyezési Hét (TKH) katonai kiképzéssel járó fizikai és pszichés terhelés következményeinek vizsgálata volt. A táplálkozáselemzés eredményei szerint az étkezések túl sok zsírt és csak gyorsan felszívódó, magas glikémiás indexű szénhidrátot tartalmaztak. A mikroelemek közül különösen magas volt a koleszterin, a nátrium és a foszfor értéke. A fizikai aktivitást tekintve az átlagos lépésszám 118 000 lépés/hét volt, ami körülbelül 98 km/fő/hét. A BMI-érték alapján a résztvevők 55%-a tartozott a túlsúlyos vagy elhízott kategóriába, a résztvevők 65%-ánál pedig emelkedett testzsírszázalékot mértek. A kiképzés végére a magas BMI-vel rendelkező katonák testösszetételi mutatóiban pozitív változást tapasztaltunk. A Berlin-kérdőív szerint négy ember szenvedett alvási apnoéban, a résztvevők 40%-a aludt napi 7 óránál kevesebbet, és körülbelül 50%-uknak az alvásminősége nem volt megfelelő. A kiképzés harmadik napjától nőtt az alvászavarok aránya. A szívfunkció- és a szívstresszértékek átlaga (három, illetve két fő kivételével) megfelelő volt. Eredményeink szerint a reggeli stresszértékek szignifikánsan alacsonyabbakká váltak az alváshossz növekedésével. A BDI-SF pontértékei alapján valószínűsíthető, hogy két személy közepesen súlyos depresszióban szenvedett.

The Impact of Space Missions on Humans 2

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Keywords human factor, emotional responses, psychological impacts, disturbed perceptions, recovery, relationships

Abstract *Space exploration has entered a phase where we now have enough valuable details and experience to make it a realistic goal to leave the safety of Earth for extended periods. These journeys will be carried out on long-duration missions, with the Moon as the first target, and eventually, with sufficient knowledge, to Mars. NASA's Artemis program plans to conduct a manned mission to the Moon by 2030, aiming to establish a base that will serve as a foundation for the first human mission to Mars by 2040. Successful long-term space exploration necessitates careful attention to the human factors essential for sustaining these missions. These long-duration, isolated missions are unfamiliar to humans, where, beyond the physical challenges, the mental, relational, and psychological stresses will also be extremely significant. It is important to study the effects of these factors.*

INTRODUCTION

In the first part of the article, I analyze in detail the effects of space on the human body and organs, revealing that no area of the human body remains unaffected by the harsh and challenging environment of outer space. Although the number of these factors and effects is almost infinite, and new discoveries are constantly emerging thanks to the ongoing missions, the exploration of these effects is far from complete. NASA's Human Research Program has highlighted five essential hazards that astronauts will encounter in space: space radiation, isolation and confinement, distance from Earth, gravity (and the lack of it), and closed or hostile environments. This is called RIDGE, a mosaic word derived from the names of the above factors.[1] Beyond physical factors, psychological, relational, and sensory impacts play an equally significant, if not greater, role

1 O'Shea, A. Claire, NASA: *5 Hazards of Human Spaceflight.*

in how space affects us as whole beings. Space presents an environment unlike anything experienced on Earth, where the absence of gravity, altered light cycles, and confined spaces lead to significant sensory and psychological challenges. Astronauts must adapt to weightlessness, which alters their sense of balance, spatial orientation, and perception of movement.[2] Prolonged exposure to such conditions can disrupt the body's natural rhythms, affecting sleep, cognition, and overall well-being. For example, astronauts frequently report a reduced sense of taste and smell, which is linked to fluid shifts in the body that resemble nasal congestion, affecting their ability to perceive flavors.[3] In addition to sensory disruptions, psychological effects play a major role during long-duration space missions. Isolation from Earth, confinement with a small crew, and the stress of operating in a dangerous, alien environment can take a toll on mental health. Disorientation can heighten anxiety and stress, further intensifying the already challenging conditions of space travel. As we look toward humanity's long-term space ambitions, the challenges increase in complexity and scale. In the short term, the focus is on mitigating the effects of microgravity, isolation, and confinement during missions on the International Space Station (ISS). For the medium term, we must address the greater isolation and distance from Earth that will come with extended stays on the Moon, where astronauts will face partial gravity as a new adaptation challenge. Looking further ahead, the long-term goal of colonizing Mars will involve coping with even greater distances, extreme isolation, the lack of gravity during transit, and the need to adjust to partial gravity on the Martian surface.

The unique combination of sensory deprivation and psychological strain requires focused research and the importance of developing comprehensive strategies to ensure astronauts' well-being and optimal performance on future missions, especially as humanity looks to extended stays on the Moon and Mars.

SLEEP IN SPACE

During a space mission, it is often challenging to provide the crew with a sufficient quantity and quality of sleep. It is well-documented that sleep deprivation increases the likelihood of errors, which can be critical in such an unusual environment.[4] Studies have also shown that exhausted, fatigued individuals often struggle to recognize or acknowledge that they are not operating at full capacity.[5] Space professionals also experience negative effects from sleep deprivation, confronting disruptions to their circadian rhythms, which deteriorate neu-

2 Carriot, Jérome et al.: *Challenges to the Vestibular System in Space: How the Brain Responds and Adapts to Microgravity.*

3 Olabi, A. A. et al.: *The Effect of Microgravity and Space Flight on the Chemical Senses.*

4 Harrison, Yvonne, Horne, James: *Sleep loss impairs short and novel language tasks having a prefrontal focus.*

5 Flynn-Evans, Erin et al.: *Risk of Performance Decrements and Adverse Health Outcomes Resulting from Sleep Loss, Circadian Desynchronization, and Work Overload.*

rological responses and exacerbate existing stress. Inadequate sleep routines and a demanding work pace can lead to deficiencies that jeopardize the success of the mission and ultimately the safety and well-being of those on board. The nature of sleep in space is often compromised due to the highly variable light and dark cycles on the different space stations and inadequate illumination during daytime hours inside the habitat. Additionally, even the habit of looking out of the window before sleeping can send misleading signals to the brain, leading to inadequate sleep rhythm. According to former ESA (European Space Agency) astronaut Tim Peake's report, a major mistake is made if someone looks at the Sun before sleeping for any reason, as it can lead to significant difficulties falling asleep. This is because the intense ultraviolet radiation from the Sun halts the body's production of melatonin, the hormone responsible for regulating sleep. This disruption can completely confuse the circadian rhythm, making it extremely difficult for the individual to fall asleep for hours.[6] In light of this and other reports, it is clear that light is the primary factor disrupting circadian rhythms. The frequency of the phenomenon adds to the challenge, as the space station orbits the Earth every 1.5 hours, resulting in 16 sunrises and sunsets each day. Even with careful attention, complete relaxation remains elusive, as work on space stations is constant. Various spacecraft regularly arrive, and the schedule for experiments must be strictly adhered to. Noise levels are notably high on such stations due to the constant operation of ventilation systems and air circulators, which are essential for maintaining the proper living conditions required for humans accustomed to Earth's environment. A decade-long research of over 80 space travelers found that most needed to take powerful sleep aids to obtain sufficient sleep quality, additionally, 75% of spacecrew use hypnotics for better rest. The research indicated that although astronauts typically aim for 8.5 hours of sleep, they were only able to achieve around 6 hours of restful sleep, even with the use of medication.[7]

Figure 1: In weightlessness, it does not matter what position we sleep in relative to our surroundings (https://www.standard.co.uk/news/tech/astronauts-struggle-to-sleep-a4555931.html /24-09-20/ *Downloaded: 20.09.2024.)*

As early as the Apollo program, researchers studied the factors affecting sleep quality and found that certain conditions positively influenced rest. These factors were as follows: All astronauts on board the spacecraft must sleep at the same time, and work should be organized to allow for at least a 6-hour break from radio transmissions every 24 hours. The disruption to the circadian rhythm should be minimized. Crew members should be able to remove their

6 Peake, Tim: *Ask an astronaut.*

7 Christiansen, Anna: *Ten-year astronaut sleep study reveals widespread use of sleeping pills in space.*

work attire before sleeping, and dedicated sleeping areas must be designated. Restraints should be provided to prevent astronauts from floating and colliding with objects or each other during sleep. The temperature should be kept comfortable, the brightness of equipment should be reduced, and eye masks should be provided to block out light. Additionally, fan speeds should be lowered to reduce noise levels. On the ISS, shift work may be implemented, with blue and red teams alternating during rotation phases. Otherwise, the entire crew sleeps simultaneously, following a schedule based on Greenwich Mean Time, typically from 9:30 pm to 6:00 am. Each astronaut has a private "closet", which is dark and somewhat soundproof. They climb into a sleeping bag, zip themselves in, and secure the bag to the wall to prevent it from floating.[8]

STRESS

One of the greatest challenges during a space mission is the time spent in this hostile environment, as it is significantly different from life on Earth and presents numerous sources of stress. These can include, but are not limited to, noise, workload, microgravity, confinement, limited social interactions, and poor sleep. The longer a mission lasts, the more this exposure affects astronauts, which can, in turn, negatively impact their physical and mental well-being, as well as their overall performance. In some cases, the so-called long-term spaceflight composite stress (LSCS) may lead to depression and cognitive impairment partly by disrupting the brain's neuroplasticity. Like in space, analog settings on Earth – isolated settings combined with extremely threatening environmental challenges – can easily lead to profound psychological changes (depression, mood instability) even in remote ground-based situations (e.g. Antarctic research station as space analog) and emotional downgrading (negative patterns) can interfere with proper verbal and written communication among team members.[9] These effects warrant significant attention. As space exploration advances and more entities enter the field, we are inevitably moving toward a future where more people will be sent to space and experience the challenges of living in such an extreme environment. Private space companies, such as SpaceX, are openly aiming to colonize Mars. In these unprecedented missions, as well as in the growing field of space research today, humans remain the critical link for successful execution. This makes it essential to focus on the human factor, particularly from a psychological perspective. Decades of experience have shown that individuals working in space are subjected to significant stressors, often leading to undesirable outcomes. These stressors can trigger psychological issues such as anxiety, depression, and

8 Day, Dwayne A.: *Working on the Moon.*

9 Ehmann, Bea et al.: *Emotionality in Isolated, Confined and Extreme (ICE) Environments: Content Analysis of Diaries of Antarctic Winteroverers.*

cognitive decline.[10] NASA has conducted research in this area and released data indicating that 85.2% of female astronauts and 22.8% of their male counterparts experience symptoms of anxiety. The numbers shift slightly when it comes to depression, with 43.2% of women and 34.8% of men reporting similar symptoms. These findings are significant and highlight the psychological challenges faced by astronauts in space. In addition, further studies have found that during missions lasting several hundred days, stress-induced mental disorders appeared in 60% of the individuals examined.[11] The majority of astronauts returning from missions reported cognitive and functional impairments, which clearly point to the malfunctioning of the central nervous system.[12] NASA, in collaboration with Roscosmos, conducted an experiment where individuals stayed on the International Space Station for a year. One of the participants had an identical twin who remained on Earth. The examination of the twin brothers revealed that the sibling who stayed in space was still experiencing cognitive problems six months after returning. With this in mind, researchers must carefully plan and implement effective prevention and recovery strategies if we aim to successfully carry out deep space missions.[13] To this day, research on the central nervous system remains one of the most relevant topics from the perspective of the human factor. At the same time, the brain's ability to adapt to new stimuli and environments, known as neuroplasticity, is gaining increasing attention in the field of study. A thorough understanding of this factor will be essential for achieving our future ambitions. This adaptive mechanism may help explain the neurobiological basis of depression and cognitive discrepancies during long-term space missions. This paper explores the combined stressors that affect astronauts' emotions and cognition during long-term spaceflight and examines the neurological basis of these effects, particularly focusing on neuroplasticity, as well as potential countermeasures to address cognitive and emotional challenges. Going further for longer deep-space missions, even the possible deterioration of cognitive performance should be calculated due to the high intensity of cosmic radiation. The microgravity itself through different changes in cerebral perfusion (due to the cephalad shift) can contribute to the deterioration of certain cognitive functions based on comparison with ground-based head-down tilt bedrest.[14, 15]

10 Yin, Yishu et al.: *Long-term spaceflight composite stress induces depression and cognitive impairment in astronauts—insights from neuroplasticity.*

11 Friedman, Eric, Bui, Brian: *A Psychiatric Formulary for Long-Duration Spaceflight.*

12 Clément, Gilles, Thu Ngo-Anh, Jennifer: *Space physiology II: adaptation of the central nervous system to space flight—past, current, and future studies.*

13 Garrett-Bakelman, Francine E. et al.: *The NASA Twins Study: A multidimensional analysis of a year-long human spaceflight.*

14 Cherry, Jonathan D. et al.: *Galactic Cosmic Radiation Leads to Cognitive Impairment and Increased aβ Plaque Accumulation in a Mouse Model of Alzheimer's Disease.*

15 Barkaszi, Irén et al.: *Are head-down tilt bedrest studies capturing the true nature of spaceflight-induced cognitive changes? A review.*

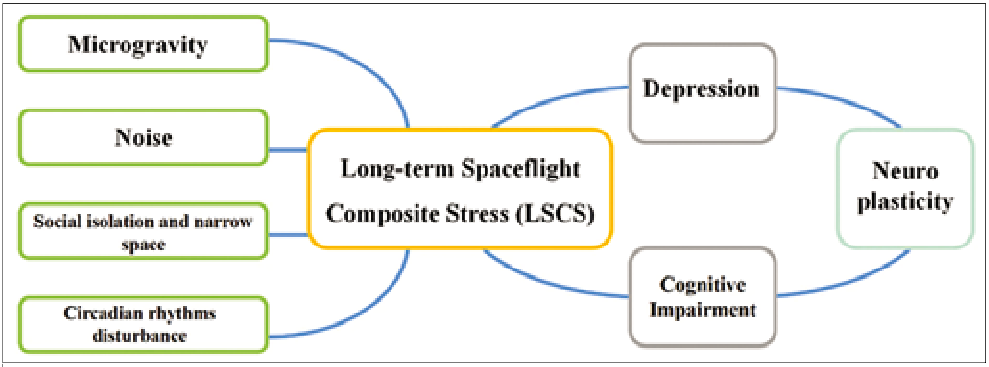

*Figure 2: Illustrative model of stress development in astronauts (*https://www.nature.com/articles/s41398-023-02638-5/figures/1 *Downloaded: 20.09.2024.)*

EMOTIONAL EFFECTS

Long-Duration Space Explorations (LDSEs), or Long-Distance Space Exploration Missions (LDSEMs), such as missions to Mars, may last up to 30 months. On shorter missions, space agencies have managed emotional challenges through preventive measures (selecting the "right stuff") and protective strategies (countermeasures). However, these approaches may not suffice for LDSEs, where even highly experienced astronauts can encounter adaptation issues and emotional disturbances.[16] For instance, during his 211-day mission on the Salyut 7 space station, cosmonaut Lebedev exhibited typical symptoms of depression, including irritability, anhedonia, and sleep disruptions. If left unchecked, affective disorders could, in the medium to long term, negatively affect team dynamics, communication, sleep quality, and cognitive and executive functions, and potentially hinder the crew's ability to respond to emergencies.[17] A study on long-duration spaceflights declared that the third week marks a turning point, as attention tends to diminish the most due to the challenges of adapting to the extreme environment.[18] In the early days, astronauts aboard the Skylab and Salyut space stations were predominantly from a single nation and spent several months on board. However, today's scenario is different. The International Space Station (ISS) hosts a multicultural environment where scientific research is conducted by crews from diverse linguistic and cultural backgrounds. While this diversity may not cause extreme difficulties, it does measurably increase stress levels. At the same time, there are positive aspects to this environment when

16 Salas, Eduardo et al.: *Teams in Space Exploration: A New Frontier for the Science of Team Effectiveness.*

17 A van Kleef, Gerben et al.: *Emotional influence in groups: the dynamic nexus of affect, cognition, and behavior.*

18 Manzey, Dietrich et al.: *Mental performance in extreme environments: results from a performance monitoring study during a 438-day spaceflight.*

viewed through the lens of emotional well-being. The collaborative efforts between nations have eliminated the host/guest dynamic often observed on earlier space stations, significantly reducing the anxiety caused by isolation.

In the near future, we will establish a foothold on the Moon and set up a base there, using the experience gained to send humans to Mars. We have already discussed the mental and physical challenges that arise during space travel, but this extremely long-duration and long-distance mission will magnify those issues. Considering the distance between Mars and Earth, communication between Mission Control and the crew will experience a delay of approximately 25–30 minutes. This delay not only limits real-time responses during unexpected situations but also significantly impacts crew morale and their sense of safety negatively. Experts are already developing various protocols to improve communication efficiency, even though signals traveling at the speed of light cannot be made faster. Alternative solutions are necessary, such as sending periodic summary "packages", using text-based messages, and optimizing the content of each message for maximum effectiveness. Personnel on a trip to Mars will not be able to rely on real-time communication with Mission Control to coordinate their schedules or activities, meaning they will need to operate with a higher level of autonomy compared to astronauts aboard the International Space Station.

While research from Earth-based space simulations indicates that crews can still meet mission objectives under autonomous conditions, more investigation is needed to understand how reduced contact with Mission Control affects crew dynamics and collaboration. Typically, Mission Control offers immediate guidance for dealing with issues or emergencies, but this real-time assistance will be unavailable on a Mars mission. To address this challenge, scientists could design simulations on Earth where varying levels of communication with Mission Control are tested.[19] This would help researchers observe how crew members interact, how well they cooperate, and how effectively they complete tasks when working independently. Spending extended periods of time in close quarters with a small group can create tension and conflicts among crew members. It has been revealed that when interpersonal stress arises, astronauts may redirect their frustration toward Mission Control, blaming them for scheduling issues or insufficient support. This can generate misunderstandings and strained communication between the crew and ground control. A potential solution to manage this tension is to set aside time each week for the crew to openly discuss any interpersonal conflicts in scheduled sessions. Research has shown that supportive commanders can significantly enhance team unity.[20] A commander with a focus on emotional support, or someone trained in conflict resolution, could lead these discussions to help crew members address and resolve their issues before they escalate and jeopardize the mission.

Spending extended time away from home can take a toll on astronauts' morale. They often feel the absence of their

19 Dingfelder, Sadie F.: *Mental preparation for Mars.*
20 Barratt, Emma: *The psychological challenges of putting humans on Mars.*

*Figure 3: In this image, Earth is seen as photographed by the Voyager spacecraft, effectively conveying the size of our planet and the sense of uncertainty this perspective can evoke (*https://www.businessinsider.com/nasa-voyager-pale-blue-dot-photo-30th-anniversary-2020-2 *Downloaded: 02.10.2024.)*

loved ones and express worry about the well-being of family members back on Earth, particularly if a family member is ill or facing a crisis. To simulate the conditions of a Mars mission, researchers could send astronauts to the lunar space station Gateway for six-month intervals, incorporating elements such as delayed communication, greater autonomy, and distant views of Earth to mimic the outbound and return phases of the mission. The length of the mission itself will also impact crew members. A Mars mission is broken into three key phases: the journey to Mars, the stay on the Martian surface, and the trip back home. Each phase presents different challenges—while the excitement of exploring Mars could boost morale, the monotony of the return journey might lead to a decline in spirits. For those who orbit planet Earth, the view of their home planet offers a comforting reminder that family and friends are still relatively close. However, for those journeying to Mars, watching Earth gradually diminish into a tiny speck in the distance may evoke a strong sensation of isolation and homesickness. Equipping the spacecraft with telescopes that allow the crew to view Earth as a vibrant sphere in space or providing virtual reality experiences of familiar landscapes and loved ones could help alleviate the emotional impact of Earth's vanishing presence. However, these methods could also risk amplifying feelings of loss as astronauts reflect on what they are leaving behind.[21]

TASTE IN SPACE

Since the beginning of space exploration, astronauts have observed changes in how nourishment tastes in orbit. Some report that foods seem flavorless, while others notice that their preferred dishes lose their appeal. Interestingly, some astronauts develop a liking for foods they would not usually enjoy, while others claim they experience no noticeable change in taste at all. Astronauts

21 Kanas, Nick: *The psychological challenges of a long voyage to Mars.*

frequently opt for bold-flavored foods to counteract the dulling of their taste sensations in space.[22] Diet requires multiple senses, such as sight, hearing, taste, touch, and smell. For instance, when enjoying an apple, we rely on various sensations: the sweetness or sourness, the aroma, the crunch, the color, and the texture. If any of these senses are diminished, our pleasure in food changes. In space, the experience of eating differs greatly from what we are accustomed to on Earth. One reason for this could be the absence of gravity. In microgravity, bodily fluids are not pulled toward the feet but instead shift toward the head, creating a sensation similar to nasal congestion. Just like when one has a cold, this affects the sense of smell, which in turn reduces the ability to taste and enjoy food.

The environment in space is both unfamiliar and persistently repetitive, which may also alter the way we perceive food. The context in which we eat plays a significant role in our overall experience. Research has demonstrated that consuming the same meal in dissimilar environments can lead to non-identical reactions and preferences. A spacecraft is a confined, enclosed space where astronauts are surrounded by equipment and wiring, with no clear separation between work and personal areas, which may influence how they experience their meals.[23] Australia's Royal Melbourne Institute of Technology aimed to explore factors that might affect appetite in zero gravity.[24] Rather than testing their hypotheses aboard the ISS, they chose a more straightforward method using virtual reality headsets. Fifty-four volunteers donned VR goggles that simulated a room on the ISS and were asked to smell samples of lemon essential oil, along with vanilla and almond extracts. They then compared these scents to how they experienced them in a typical earthly environment. Overall, participants reported that the sweeter vanilla and almond aromas were stronger in the VR space setting, while the intensity of the lemon scent remained consistent, even though they were still physically on Earth. A series of tests combined with virtual reality ultimately proved that the sense of taste of the participants in the study did indeed change in a measurable and describable way. The food chemists on the team identified benzaldehyde, a sweet-scented compound, as a potential explanation for the heightened sensitivity to certain aromas. Researchers suggest that enhancing food aromas could significantly improve astronauts' appetites in future space missions. This approach, however, is not limited to space travel. According to the research, the findings from this study could also help customize diets in socially isolated settings, such as nursing homes, and boost nutritional intake. Though further research is required, incorporating compounds like benzaldehyde into astronaut meals may soon become a key strategy for improving their dining experience both on the ISS and during future missions.[25]

22 NASA's Space Operations Mission Directorate: *Matter of taste.*

23 Low, Julia et al.: *Astronauts don't eat enough because food tastes bland in space. We're trying to work out why.*

24 Paul, Andrew: *Why food tastes more bland in space.*

25 Loke, Grace et al.: *Smell perception in virtual spacecraft? A ground-based approach to sensory data collection.*

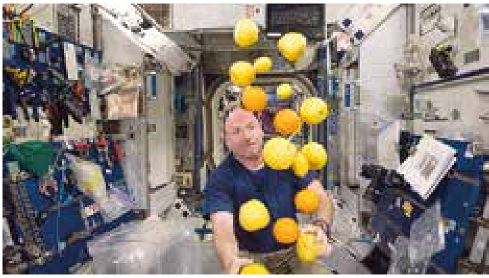

*Figure 4: A rare treat aboard the International Space Station: fresh, delicious fruit (*https://eu.jsonline.com/story/entertainment/books/2017/10/13/endurance-astronaut-scott-kelly-chronicles-his-year-space/747945001/ *Downloaded: 02.10.2024.)*

SUMMARY

Human experience in space has now been several decades, giving us a better understanding of how the body adjusts to life beyond Earth. However, with plans for further space industrialization and exploration of distant planets, humans will need to endure much longer periods in space. Most current data comes from shorter missions, meaning that many extended physiological impacts remain unknown. A voyage to Mars using today's technology is estimated to require at least 18 months of travel time. Preparing for such journeys stands in need of a deep understanding of how the body reacts to increased time in space. Onboard medical facilities must be able to handle various health issues and emergencies and be equipped with a broad range of diagnostic tools and treatments to maintain crew health throughout the mission. So far, only well-trained and rigorously tested astronauts have been exposed to space environments. As off-world colonization becomes a possibility, a wider variety of people, including children, will face these risks, and the effects on younger individuals remain unexplored. Presently, there are approximately 700 highly trained astronauts (580 male, 90 female), who are selected with scrutiny. When astronaut John Glenn, a member of the original Mercury 7, returned to space at age 77 in 1998, his nine-day mission gave NASA valuable data about the impact of space on older adults. Factors such as dietary needs and living circumstances, which have not yet been thoroughly examined, will become increasingly relevant. Overall, there is limited knowledge about the full spectrum of impacts that living in space has on a human as a whole, making it difficult to address all potential risks. The International Space Station is currently being used as a platform to study these hazards. Space remains largely uncharted, with likely still unknown dangers. However, future technologies like artificial gravity and advanced life support systems may eventually help reduce some of these risks. Colonization (mining and manufacturing) is much more complex than a longer EVA (extravehicular activity), so it will be crucial to plan and master these activities accurately in order to execute them effectively. From Earth to Orbit: the ISS can provide a "sea-level home" with reasonable weight and volume (still cost-effective) limits. From ISS to deep space: a much smaller "independently-run" home with much fewer resources. Optimal space medicine tools need to be specified. New health risk models are needed for BLEO (beyond low Earth orbit) to ensure that the risks of human presence are reduced.

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AZ ŰRMISSZIÓK EMBERRE GYAKOROLT HATÁSA 2.

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Kulcsszavak emberi tényező, érzelmi reakciók, pszichológiai hatás, érzékelési zavar, felépülés, kapcsolatok

Absztrakt *Az űrkutatás napjainkban egy olyan szakaszba lépett, ahol már megfelelő mennyiségű értékes adat és tapasztalat áll rendelkezésünkre ahhoz, hogy reális cél legyen elhagyni a Föld nyújtotta biztonságot hosszabb időre is. A hosszú távú küldetések során, az első cél a Hold lesz, majd – kellő tudás és tapasztalat birtokában – a Mars. A NASA Artemis programjának keretén belül tervezik, hogy egy legénység legfeljebb 2030-ig elutazik a Holdra, ahol egy olyan bázis létrehozása a cél, amely szilárd alapot biztosít az első emberi Mars-küldetéshez 2040 környékére. A hosszú távú űrkutatás sikeres megvalósítása érdekében gondos előkészületek szükségesek az emberi tényező terén, mivel ezek elengedhetetlenek a küldetések fenntartásához és sikeres végrehajtásához. A hosszú, elszigetelt missziók az emberek számára ismeretlenek, és a fizikai kihívásokon túl a mentális, kapcsolati és pszichológiai stressz is rendkívül jelentős lesz. Kulcskérdés tanulmányozni és értelmezni a vizsgálni kívánt tényezők hosszú távú hatásait.*

Pilot Training in the Virtual Sky: The Application of Simulators in the Development of Movement Coordination and its Applicability in Rehabilitation

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Keywords simulator, rehabilitation, Mi-17 FTD, DCS, development, coordination

Abstract *In today's fast-paced world, the spread of simulators extends to numerous fields, as their targeted application can lead to significant improvements within a specific sector. The optimal use of simulator-based training in pilot education is indispensable in a modern military Air Force, and their utility in developing and enhancing movement coordination is unquestionable.*

INTRODUCTION

The synchronized operation of body and mind holds paramount importance in our daily lives and activities. Developing movement coordination is essential among aviators as it significantly influences their work efficiency and contributes to maintaining and improving their health. Numerous studies confirm that the use of simulators has resulted in remarkable individual development, aiding in the establishment of proper movement patterns and even supporting rehabilitation.

Movement coordination involves the optimal and purposeful execution of movements in space and time, requiring the fulfillment of multiple factors for coordinated movement to occur. This ability enables us to precisely and efficiently control our body movements (adjusting muscle strength to the power magnitude and direction executing flight control maneuvers) and synchronize them with our environment. It encompasses not only muscular development but also communication between the nervous system and the brain. Simulators can assist in this process by offering several advantages that can improve hand-eye-foot coordination on an individual level.

One of the primary advantages of simulators is the opportunity to practice in a safe environment. In pilot training, novices lack the necessary skills and familiarity with the environment they will encounter. Despite theoretical knowledge, real-world scenarios can differ significantly. Aviation involves numerous risks that pilots must handle professionally and in a calm mental state. Exposing trainees to these potentially hazardous situations in a simulator allows them to develop themselves and form ingrained responses in a risk-free setting. These responses can then be activated reflexively in real-life situations, potentially influencing life-or-death decisions.

It is also worth highlighting the significant variety of functions, situations, and activities that a simulator can generate for trainees. Different difficulty levels can be set, providing continuous feedback to individuals and allowing them to react and improve in real time. When using a simulator for developing movement coordination, we always adhere to the principle of progression. Initially, we focus on establishing basic movement patterns during the first phase, and once proficiency in these fundamental movements is achieved, we gradually introduce more complex tasks into the training program.

APPLIED SIMULATORS

As part of my doctoral research, I have set the goal of optimizing simulator-based training and formulating a new educational methodology, with the development of movement coordination in a safe environment as a cornerstone. The first step towards this goal is creating a module that can be used at home. In this case, trainees can practice using various software tools in the comfort of their home environment. The desired outcome for individuals is to use simulators purely for the experience and enjoyment, free from stress and pressure. Experiences over the past few years confirmed that movement coordination skills have developed unconsciously through the use of the suggested simulators by students. During gameplay, they focused solely on the task at hand without focusing on coordinating their own movements, simply enjoying the simulation experience. Through repeated practice over several days, their executions became more and more accurate and precise, eventually developing the required reflexes.

Digital Combat Simulator

DCS[1] is a combat simulator available for free civilian use, capable of accurately modeling the characteristics of various aircraft. There are numerous aircraft types to choose from; in my case, the Mi-8MTV2 helicopter type was the appropriate choice, as it closely resembles the Mi-17 FTD[2] used in training.

It is important to note that for proper simulation, it is necessary to connect some compatible controller package to the software, as this is the only way to achieve proper eye-hand-foot coordi-

1 Digital Combat Simulator.

2 Flight Training Device.

Figure 1: Digital Combat Simulator Mi-8MTV2 view in VR mode (Source: edited by the author)[3]

nation. During my experiments, I used the Thrustmaster T-16000M FCS flight pack, which includes a joystick, a throttle, and pedals. Additionally, I calibrated a VR headset and a yaw motion chair (a chair that provides rotational movement around 3 axes), but during the experiment, I only used the Thrustmaster package. It is possible, albeit with a significant increase in cost, to replace the throttle with a separate, special collective lever, which is not necessarily required for mastering basic skills.

I conducted the experiment with the help of students from different study groups, with some joining in the later stages of the testing phase for comparison purposes. The initial goal of the game was to master basic flight techniques, after which tasks gradually became more complex. It took approximately 5 hours to master landings and hovering maneuvers, during which significant improvements in movement coordination were observed in both participants. Over time, the frequency of rough movements decreased, and

Figure 2: DCS calibration using VR and yaw motion chair

3 Virtual Reality.

attention shifted not only to the accuracy of steering but also to understanding helicopter flight characteristics.

In the case of helicopters, where three control surfaces must be coordinated in four dimensions, continuous work on movement coordination was necessary. After five hours of flight, landings were made more difficult by using various platforms such as tight spaces, stationary and moving warships, or moving tankers. These tasks required precise movement coordination, as these landing spots were extremely challenging to approach and required calm steering and gentle movements for successful completion.

Throughout the tasks, students were required to verify successful execution with a video playback. The most complex task, landing on a moving tanker ship, was achieved after approximately 10–12 hours of software use, after which only the length and composition of the tasks changed.

Mi-17 FTD simulator

In the next phase, the trainees continued the experiment with the Mi-17 FTD located at the Hungarian Defence Forces 86th Helicopter Wing. The two cadets who had gained stable motor coordination experience in the DCS transitioned to the real simulator. The rest of the study group joined the experiment here with the goal of measuring differences in piloting skills. Those two students who completed the DCS already possessed comprehensive cockpit familiarity, knowing the positions of controls, levers, and switches, and were thus able to navigate comfortably within the cockpit. They would have been capable of starting and shutting down the aircraft if the task had demanded it, although this was not relevant for the purposes of the experiment. For the other trainees, developing this basic cockpit familiarity resulted in a loss of time.

During simulator training, significant differences in motor coordination were observed among students who had previously familiarized themselves with basic procedures in the DCS. The hypothesis before the study, that modern civilian gaming software is suitable for acquiring fundamental helicopter piloting skills and can lead to outstanding development in motor coordination, was fully confirmed by this experiment. In the Mi-17 FTD simulator, students faced real control forces, weather conditions, and aerodynamic effects, all adjustable by an external operator. From the first hour, the two trainees were able to maintain the helicopter in hover mode and perform basic position changes without difficulty. Essentially, the initial hour served for them to familiarize themselves with and adjust to the simulator's nuances. Subsequently, they had to repeat the tasks with the autopilot turned off. During these repetitions, many aids that had previously assisted the students were removed, forcing them to rely entirely on their own skills. Precise, continuous adjustments of multiple control surfaces became crucial, as rough movements could render the helicopter uncontrollable. Apart from the first hour of the experiment, the two trainees flew without using autopilot. The objective was to measure how quickly they could execute a safe landing on a restricted-size landing pad in simulated conditions and repeat these two more times, eliminating the possibility of luck. Similar to the situation with the tanker ship in the DCS, sophisticated hand-eye-foot coordination was required, necessitating approximately two additional hours of practice, leaving the remaining two hours for various airspace tasks and circuits. The experiment was conducted within a five-hour timeframe to gauge the level of the tasks achieved.

For the other members of the group, the five-hour time limit allocated for the experiment was considered suboptimal. These students encountered the Mi-17 FTD for the first time, starting from the basics. During the five hours, they managed to perform hovering with the autopilot and execute basic positional changes. Initially, the aircraft remained stable without the autopilot but soon became unstable and uncontrollable. Although some muscle memory began to develop, significantly more time was required compared to the allotted simulator usage time for regular practice. One might question why this could pose a problem, as the goal is always for students to start real aircraft operations with solid foundations. The answer lies in the size of the groups. Due to the large number of students, the time spent in the Mi-17 FTD simulator must be limited to ensure every student can use it effectively, hence the critical importance of a student's background upon reaching this stage.

Naturally, virtual reality also serves as a fertile ground for many other experiments. For example, experiments were conducted on fighter pilots, where changes in pulse and stress levels were measured.

The comparison between take-off and in-flight revealed a statistically significant increase ($p<0.05$) in percentage of consecutive RR intervals that differ by more than 50 ms from each other (pNN50), root mean square of the successive differences (rMSSD), standard deviation 1 and 2 (SD1 and SD2), and a statistically significant decrease ($p<0.000$) in stress score (SS) and in the sympathetic to parasympathetic ratio (S:PS). Between flight and landing, a statistically significant increase ($p<0.05$) in mean HR, minimum HR, maximum HR, SS and S:PS was shown, while experiencing a significant decrease ($p<0.000$) in pNN50, rMSSD and SD2. Finally, between take-off and landing, the variables which showed significant changes ($p<0.05$), with these changes being a significant increase, were mean HR, minimum HR, maximum HR, rMSSD, SD1 and SD2. SS and S:PS ratios showed a statistically significant decrease ($p<0.000$).[4]

An emergency scenario in a flight simulator triggered anticipatory anxiety in pilots, as evidenced by low HRV. This anxiety response heightened during the flight segment and diminished during the landing phase.

SIMULATOR TECHNOLOGY IN REHABILITATION

In today's conflict-ridden world, where the role of soldiers is increasingly valued, I believe there should be a strong emphasis on the rehabilitation of injured

4 Fernández-Morales, Carlos et al.: *Analysis of heart rate variability during emergency flight simulator missions in fighter pilots.*

soldiers. Whether they are injured in actual combat situations or during training, injuries or trauma may necessitate the need to restore their combat capabilities. Virtual reality (VR), augmented reality (AR), and simulators offer endless possibilities for cost-effective and productive rehabilitation.

Neurological injuries often lead to temporary or permanent paralysis of limbs in significant cases. The rehabilitation of such injuries is a lengthy and gradual process, where the individual's motivation and the rehabilitation environment play crucial roles:

– *Intrinsic Motivation:* The individual must have the intrinsic desire to recover. Despite seeming obvious, a constant and monotonous rehabilitation procedure can reduce the effectiveness of recovery due to the lack of motivation.
– *Application of VR Technology:* Utilizing diverse VR environments can activate basic motor functions and sensations that may not necessarily be associated with a normal developmental process. For instance, walking on a balance beam atop a virtual skyscraper activates balance-related functions and the instinct to "survive" more effectively than a similar exercise performed in a room.
– *Mental Rehabilitation:* For soldiers, alongside improving motor coordination, there is also an opportunity for mental rehabilitation. Placing individuals in environments they find difficult or challenging can facilitate mental recovery. This should always be done under the supervision of appropriate professionals.

By integrating these technologies and approaches, rehabilitation can be made more engaging, effective, and tailored to the specific needs and challenges faced by injured soldiers. It not only aids in physical recovery but also addresses the psychological aspects, promoting a holistic approach to rehabilitation in military contexts.

In Europe, the rehabilitation program based on VR technology developed by CUREOSITY is gaining momentum. The company has conducted numerous independent trials, including studies on stroke patients. Participants undergoing treatment based on virtual reality showed significantly greater improve-

Figure 3: Rehabilitation VR goggles used by CUREOSITY (https://www.cureosity.com/ *Downloaded: 04.07.2024.)*

ment compared to patients treated with conventional robotic methods. The company is expanding continuously, and with the increasing popularity of VR, this trend is expected to accelerate further.

SUMMARY

The 21st century is advancing rapidly towards full digitalization. Across all fields of science and industries, modern technology offers solutions and opportunities that were once unimaginable. Optimizing medical procedures, whether in civilian or military contexts, can lead to significant cost savings, remarkable cognitive and motor coordination improvements, and potentially shorten recovery times for patients. Advancements in medical technology also pave the way for studying the physiological effects of VR headsets during military training, both in air and ground operations.

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PILÓTAKÉPZÉS VIRTUÁLIS ÉGEN: SZIMULÁTOROK HASZNÁLATA A MOZGÁSKOORDINÁCIÓ FEJLESZTÉSÉBEN ÉS REHABILITÁCIÓ SORÁN

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ABSZTRAKT *Napjaink rohanó világában a szimulátorok térnyerése immár számos területre terjed ki, hiszen célzott alkalmazásuk jelentős fejlődést eredményezhet egy adott szegmensben. A pilótaképzésben használt szimulátoros kiképzés optimális alkalmazása elengedhetetlen egy modern haderőben, továbbá a szimulátorok hasznosíthatósága megkérdőjelezhetetlen a mozgáskoordináció kialakításában és fejlesztésében.*

Psychological Impact of FPV Drone Sounds on the Battlefield

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Keywords PSYOPS, psychological warfare, cyber warfare, battlefield anxiety, FPV drone

Abstract *With advances in technology, Psychological Operations (PSYOPS) have become increasingly complex, incorporating cyberspace and unmanned aerial systems as integral components of modern warfare alongside traditional tools. FPV (first-person view) drones are possible assets in the arsenal of psychological warfare, as their distinctive, wide-spectrum buzzing sound can instill fear, anxiety, and panic among enemy forces. This study examines the battlefield application of these drones within the framework of psychological warfare, focusing on their acoustic effects that evoke a sense of constant surveillance and immediate threat. Our aim is to highlight elements of PSYOPS that, in conjunction with these effects, can enhance their effectiveness.*

INTRODUCTION

PSYOPS have long been a critical aspect of warfare, with methods ranging from leaflet drops to loudspeaker operations aimed at demoralizing enemy troops. In modern conflicts, such as the Gulf War, PSYOPS included propaganda through radio broadcasts, encouraging enemy soldiers to surrender.[1] Today, with the advent of UAS (Unmanned Aerial Systems), new opportunities arise for psychological warfare. FPV drones, widely used for reconnaissance and tactical strikes, emit a characteristic buzzing sound likened to an ominous presence above the battlefield.[2] This auditory component of FPV drones is increasingly recognized as a psychological tool, capable of generating anxiety, fear, and even panic among those exposed to it.

1 *NATO STANDARD AJP-3.10.1 Allied Joint Doctrine for Psychological Operations,* 4/1.

2 Craiger, J. Philip, Zorri, Diane Maye: *Current Trends in Small Unmanned Aircraft Systems: Implications for US Special Operations Forces,* 7.

PSYCHOLOGICAL OPERATIONS

Psychological operation is a vital aspect of modern warfare, designed to influence, disrupt, and manipulate the perceptions, emotions, and behaviors of target audiences. It aims to weaken enemy morale, foster uncertainty, and create internal division. These operations are executed through various mediums, ranging from traditional methods such as leaflets, radio, and television broadcasts, to contemporary digital techniques such as social media manipulation, trolling, and the use of bots. Each of these methods plays a unique role in the overall strategy to achieve psychological dominance on the battlefield.[3]

Leaflet distribution and propaganda

Leaflet distribution has long been a core tool in PSYOPS, particularly for spreading propaganda among enemy forces and civilian populations. During World War II and the Gulf War, millions of leaflets were dropped over enemy territories, urging soldiers to surrender, demoralizing enemy troops, and providing disinformation about upcoming attacks. These leaflets often included imagery and messaging that played on the fears and insecurities of the targeted population, such as false reports of heavy losses or imminent large-scale attacks. In modern conflicts, leaflets continue to be used in combination with more advanced digital techniques, creating a multi-layered psychological assault. Leaflets serve several purposes, including demoralization by promoting the futility of resistance or the inevitability of defeat, deception by distributing false information to mislead enemy forces about strategic plans or the strength of forces, and appealing to civilians in occupied areas to encourage collaboration with occupying forces or resist insurgent groups.[4]

Radio and television broadcasts

Radio and television broadcasts have historically been potent tools for PSYOPS, enabling military forces to reach large audiences with persuasive messaging. During the Cold War, radio stations, such as Radio Free Europe, played a significant role in broadcasting Western ideals and anti-Soviet sentiment to eastern-bloc countries. Similarly, in the Gulf War, coalition forces used radio to broadcast messages to Iraqi soldiers, encouraging them to surrender and desert their posts.[5] In modern conflicts, the use of satellite television has enabled PSYOPS to reach even larger audiences, bypassing state-controlled media. For example, television broadcasts were utilized during the Iraq War to show footage of advancing coalition forces, spreading fear and demoralization among Iraqi troops and civilians alike. These broadcasts

3 Haig, Zsolt: *Információs műveletek a kibertérben,* 262–265.
4 *NATO STANDARD AJP-3.10.1 Allied Joint Doctrine for Psychological Operations,* 4/1-4.
5 Bouchard, Ronald M.: *Information Operations in Iraq*, 8.

often serve to instill fear by showcasing overwhelming force and advanced technology and to spread disinformation by broadcasting false information about the enemy's capabilities, plans, or internal divisions.

Loudspeaker operations

Another traditional yet effective PSYOPS tactic is the use of loudspeakers to project messages directly to enemy forces on the front lines. Loudspeakers have been employed in numerous conflicts, including the Korean War and Vietnam War, to spread demoralizing messages and encourage enemy troops to surrender. The loudspeaker approach is particularly effective in close combat situations where direct auditory contact can cause confusion, fear, and psychological strain. These messages often focus on encouraging defection by persuading enemy soldiers to abandon their positions or surrender under promises of good treatment, and psychological harassment by continuously exposing enemy troops to demoralizing messages, breaking down their resolve over time. Loudspeaker operations work by leveraging the element of surprise and immediacy. Hearing a message directly can have a stronger psychological impact than reading a leaflet or receiving a broadcast from afar. Moreover, the use of native languages and dialects in loudspeaker broadcasts adds an element of familiarity and trustworthiness to the message, further enhancing its effect.[6]

CYBER PSYOPS

In today's digital age, the internet has become a new battleground for psychological operations, often referred to as cyber PSYOPS. These operations leverage the vast reach of social media and digital platforms to spread disinformation, manipulate public opinion, and create internal divisions within target populations. Cyber PSYOPS are utilized by both state and non-state actors to advance strategic objectives, ranging from political influence to undermining adversaries. The use of trolls, bots, and fabricated news stories has become a widespread tactic in these campaigns, contributing to the growing challenges of information warfare.[7]

Trolling as a weapon of manipulation

Trolling is one of the most common methods used in cyber PSYOPS. Trolls are individuals or groups who deliberately post provocative, offensive, or misleading comments on social media and online forums to elicit emotional reactions, distract from important issues, or incite conflict. Their goal is often to

6 Celeski, Joseph D.: *Psychological Operations - A Force Multiplier,* 356.

7 Deák, Veronika: *Social engineering alapú információszerzés a kibertérben megvalósuló lélektani műveletek során,* 97.

polarize public opinion, divert attention, or amplify existing tensions within a society. Trolls may be motivated by ideological beliefs, financial incentives, or state sponsorship, and they frequently operate anonymously or under false identities to evade detection. State-sponsored trolling campaigns are particularly effective because they are coordinated and often involve large numbers of accounts working in tandem to spread specific narratives. By creating an illusion of widespread support or opposition, trolls can influence public discourse and shape perceptions of reality. This tactic is particularly dangerous because it exploits the human tendency to conform to perceived social norms, leading individuals to adopt beliefs or behaviors that they might otherwise reject.[8]

Bots in information warfare

Bots are automated accounts programmed to spread messages, amplify content, or engage with users on social media platforms. Unlike human trolls, bots can operate at an enormous scale, posting thousands of messages in a short period. This capability makes them a powerful tool for cyber PSYOPS, as they can flood information channels with specific narratives, drown out opposing viewpoints, and create a false sense of popularity or consensus. Bots are often used to amplify the messages of trolls, making it appear as though certain topics or viewpoints are trending. This amplification can create a feedback loop in which real users are more likely to engage with or believe the content, further spreading the disinformation. Bots can also be used to target specific individuals or groups, overwhelming them with harassment or spreading misleading information to discredit them.[9]

Fake news

Fake news, or deliberately fabricated information presented as legitimate news, is another key component of cyber PSYOPS. Fake news stories are designed to deceive audiences, manipulate emotions, and influence beliefs or behaviors. By exploiting the trust that people place in news sources, fake news can effectively shape public opinion, create confusion, and undermine trust in legitimate institutions. The spread of fake news is facilitated by the algorithms of social media platforms, which prioritize content that generates high engagement. Sensational or emotionally charged stories are more likely to be shared, regardless of their accuracy, allowing fake news to reach large audiences quickly. This phenomenon is particularly problematic during times of crisis or political instability, when people are more susceptible to believing and sharing misleading information.[10]

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8 Mabima, Joseph: *Social Networking Sites as a Tool of Psychological Operations: A Case Study*, 61–63.
9 Mabima, Joseph: *Social Networking Sites as a Tool of Psychological Operations: A Case Study*, 12.
10 Gelev, Igor, Popovska, Biljana: *Fake News as Part of the Information Operations*, 57.

State and non-state actors in cyber PSYOPS

Cyber PSYOPS are conducted by both state and non-state actors, each with their own objectives and methods. State actors, such as government agencies or military units, use cyber PSYOPS to weaken adversaries, influence elections, or shape international perceptions. These operations are often well-funded and involve sophisticated techniques, including the use of artificial intelligence to generate convincing fake content or to identify and exploit societal vulnerabilities. Non-state actors, such as extremist groups, political activists, or criminal organizations also engage in cyber PSYOPS to advance their agendas. These groups may use disinformation to recruit followers, spread propaganda, or destabilize governments. The anonymity of the internet provides a low-cost, low-risk way for these actors to reach large audiences and achieve their goals.[11]

Impact of cyber PSYOPS on society

The impact of cyber PSYOPS on society can be profound. By spreading disinformation, creating divisions, and undermining trust in institutions, these operations can destabilize societies and weaken democratic processes. The use of trolls, bots, and fake news can amplify existing social and political tensions, making it more difficult for individuals to distinguish between truth and falsehood. One of the most significant challenges posed by cyber PSYOPS is their ability to exploit cognitive biases. Humans are naturally inclined to seek out information that confirms their existing beliefs, a phenomenon known as confirmation bias. Cyber PSYOPS exploit this tendency by targeting individuals with tailored disinformation that reinforces their views, creating echo chambers where false information is repeated and amplified. This can lead to increased polarization and a breakdown in social cohesion.[12]

Countermeasures for cyber PSYOPS

Addressing the threat of cyber PSYOPS requires a multi-faceted approach, involving governments, technology companies, and the general public. Governments can implement regulations to hold platforms accountable for the spread of disinformation and invest in initiatives to educate the public about media literacy and critical thinking. Technology companies, particularly social media platforms, have a responsibility to improve their detection and removal of coordinated disinformation campaigns, as well as to increase transparency around how content is promoted and moderated. Individuals also play a crucial role in combating cyber PSYOPS. By developing critical thinking skills and being cautious about the information they consume and share, people can reduce the effectiveness of disinformation campaigns. Media literacy programs can

11 Cordey, Sean: *Cyber Influence Operations: An Overview and Comparative Analysis*, 19.

12 Cordey, Sean: *Cyber Influence Operations: An Overview and Comparative Analysis*, 10.

help individuals recognize the signs of fake news, understand the tactics used by trolls and bots, and make informed decisions about what information to trust. In conclusion, cyber PSYOPS represent a significant and growing threat in the digital age. The use of trolling, bots, and fake news to manipulate public opinion and create divisions poses a challenge to societies around the world. Combating this threat requires coordinated efforts at all levels from government policy and platform accountability to public awareness and education. Only by working together can we hope to mitigate the impact of cyber PSYOPS and protect the integrity of our information environment.[13]

FPV DRONE BUZZING AS A PSYCHOLOGICAL WEAPON

In the ongoing Russia-Ukraine conflict, FPV drones are utilized as loitering munition to neutralize and destroy enemy units. As a consequence of this method, high-speed brushless direct current (BLDC) motors serve as an effective psychological tool on the battlefield, with their distinct buzzing noise. To further understand the psychological impact, we conducted measurements with a uRage Stream 750 microphone to examine the acoustic spectrum of these drones while they were maneuvering around the potential target. (Figure 1)

Our results indicated that the noise produced by FPV drones is wide-spectrum in the audible range, characterized by a broad frequency band that includes both high and low frequencies. (Figure 2) The wide-spectrum acoustic noise combined with rapid changes in sound pressure levels caused by the drone's high speed, contributes significantly to the psychological stress experienced by adversaries. This noise, often described as an eerie, mechanical hum, has significant psychological effects on both soldiers and civilians, particularly in combat zones.

Figure 1: Measurement setup for the audible recording of an FPV drone (Edited by the authors)

13 Avădănei, Angela-Karina: *Influence Operations, between the Ethical and Critical Facet,* 82.

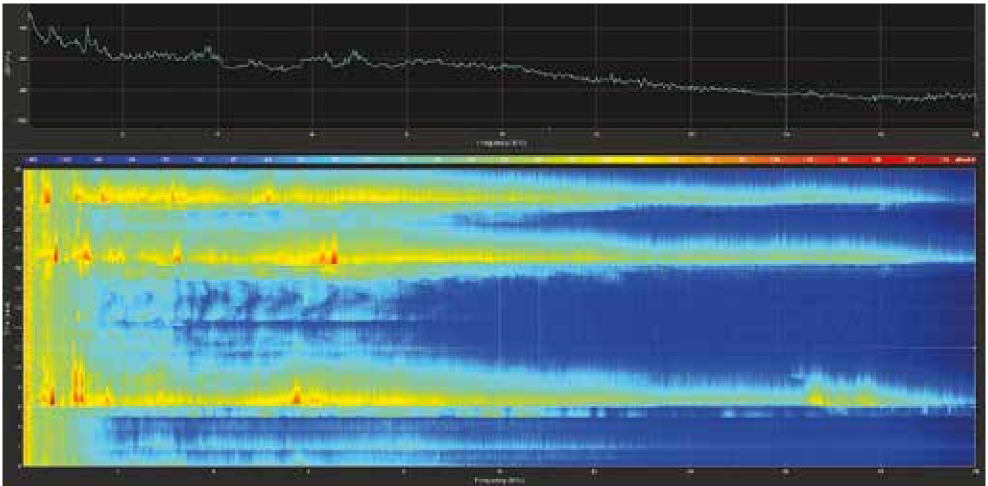

Figure 2: Spectrogram of the acoustic noise emitted by an FPV drone (Edited by the authors)

The continuous buzzing can induce feelings of dread, helplessness, and vulnerability, similar to traditional loudspeaker PSYOPS, which were historically used to demoralize enemy troops. The auditory impact is amplified when multiple drones operate simultaneously, creating an overwhelming sense of surveillance and looming danger.

The buzzing of FPV drones creates a sense of impending danger, particularly in high-stress environments, leading to increased fear and disorientation. This psychological impact is further intensified by the ability of drones to remain airborne for extended periods, thereby reinforcing the sense of being constantly watched and targeted. Their noise can be tactically weaponized to weaken enemy morale by creating the illusion of perpetual surveillance and imminent attack. Much like cyber PSYOPS, which rely on misinformation and disinformation to instill confusion and fear, the auditory element of FPV drones contributes to an environment where combatants feel exposed and hunted. This tactic mirrors traditional loudspeaker operations, where messages were broadcast directly to front lines to erode enemy morale. When employed in swarms, they can overwhelm the senses of their targets, creating a multi-faceted psychological assault that further diminishes their resolve and effectiveness.

The psychological impact of buzzing is magnified when combined with disinformation campaigns. Cyber PSYOPS can disseminate exaggerated information about the drones' capabilities, suggesting they carry advanced surveillance or lethal payloads, thereby heightening fear and anxiety among those exposed. In battlefield conditions, the psychological effects of drone buzzing are exacerbated by environmental factors, such as night operations or densely populated urban areas, where sound reverberates and amplifies disorientation. This combination of auditory, visual, and psychological stimuli represents a powerful evolution in the methods of psychological warfare. The integration of FPV drones with both traditional and cyber PSYOPS forms a comprehensive psychological attack that targets the morale and psychological stability of enemy forces. By utilizing both auditory harassment and misinformation, FPV drones create a profound psychological toll, eroding combat effectiveness and instilling a sense of helplessness. The future of psychological warfare will increasingly depend on the ability to leverage such advanced technologies to exert multi-layered psychological pressure on adversaries.

CONCLUSION

The utilization of FPV drones as part of psychological operations introduces a new, potent element to modern warfare. Our measurements demonstrated that the acoustic spectrum of these drones is wide, covering a broad range of frequencies that contribute to their unsettling effect. The distinctive buzzing sound, characterized by significant fluctuations in sound pressure due to high-speed movement, serves as an auditory reminder of an enemy's presence, which can amplify fear, anxiety, and the perception of being constantly watched. This effect is particularly powerful when combined with misinformation campaigns that exaggerate the drones' capabilities, thus enhancing the psychological toll on both combatants and civilians. The integration of FPV drones with traditional and cyber PSYOPS creates a comprehensive psychological attack strategy that not only affects individual soldiers but also impacts the collective morale and stability of entire populations. As technology advances, understanding and leveraging these psychological impacts will be critical for effective military strategy and operations in future conflicts.

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AZ FPV-DRÓNOK HANGJÁNAK PSZICHOLÓGIAI HATÁSAI A HARCTÉREN

Szerzők Farkas Gábor, a Nemzeti Közszolgálati Egyetem Katonai Műszaki Doktori Iskola doktorandusza
Fazekas Gábor, a Nemzeti Közszolgálati Egyetem Katonai Műszaki Doktori Iskola doktorandusza

Kulcsszavak PSYOPS, pszichológiai hadviselés, kiberhadviselés, harctéri szorongás, FPV-drón

Absztrakt *A pszichológiai műveletek (PSYOPS) a technológia fejlődésével egyre összetettebbé váltak, a hagyományos eszközök mellett már a kibertér és a pilóta nélküli légi rendszerek is szerves részét képezik a modern hadviselésnek. Az FPV (belső látképes) drónok eszközként szolgálhatnak a pszichológiai hadviselés arzenáljában, mivel jellegzetes, széles spektrumú zümmögő hangjukkal képesek félelmet, szorongást és pánikot kiváltani az ellenséges erők körében. Tanulmányunkban az említett drónok harctéri alkalmazását vizsgáljuk a pszichológiai hadviselés keretein belül, fókuszálva az akusztikai hatásokra, melyek a folyamatos megfigyelés és közvetlen fenyegetettség érzetét kelthetik. Célunk rávilágítani a PSYOPS azon elemeire, melyekkel összefüggésben az említett hatás fokozhatja a műveletek hatékonyságát.*

Mauritania's Medical Intelligence

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Keywords: healthcare, risk assessment, infectious disease, medical intelligence

Abstract: *This article aims to describe the public health and epidemiological risks specific to Mauritania. I will review factors that are specific to the region and country but different from those in Europe. I will analyse the demographic data, the specificities of the health system, and the environmental challenges that may contribute to the development of the above-mentioned risks.*

GENERAL OVERVIEW

Mauritania, formally known as the Islamic Republic of Mauritania, is located on the Atlantic coast of Africa and serves as a geographic and cultural bridge between the North African region and Sub-Saharan Africa. It is bordered by Senegal, Mali, Algeria, the Western Sahara, and the Atlantic Ocean. Mauritania is the 11th largest country in Africa, covering an area of more than eleven times the size of Hungary. With 90 percent of the country's territory in the Sahara, most of the population resides in the southern part of the country; most people are concentrated in the capital, Nouakchott.

Mauritania is a member of the Arab League; Islam is the official state religion and Arabic is the official language. The country, named after an ancient Berber kingdom, was historically inhabited by various nomadic ethnic groups (Black Moors, White Moors, and Sub-Saharan Mauritanians), who were organised according to a strict caste system with deep ethnic differences. These divisions have influenced subsequent power dynamics and access to resources.

Mauritania gained independence on 28 November 1960, after being a French colony since 1904. From the 1960s, the country was ruled by a one-party authoritarian regime. In 1976, Mauritania, along with Morocco, annexed the territory of Western Sahara, but the conflict nearly made the country collapse. Eventually, Mauritania became a minor player in the territorial dispute and is now supportive of a peaceful resolution. Following several military coups and successive authoritarian regimes, Mauritania held its first fully democratic presidential elections in 2007. Following a series of political upheavals, Mohamed Ould Ghazouani was elected president in 2019 and re-elected in June 2024. Today, Ghazouani contributes to the stability and maintains good relations with the United States, France, and neighbouring countries.

Mauritania is rich in mineral resources, especially iron and ore, but it remains one of the poorest countries in the world, with more than half of its population living in poverty.

MODERN SLAVERY

During the French colonial period, slavery was already fought against, but various forms of modern slavery still exist in Mauritania, although it was officially abolished three times: in 1905, 1981, and in August 2007. In addition to modern slavery, child labour, sexism, racism, female genital mutilation, forced marriage, and human trafficking must also be fought in the country. Modern slavery in Africa can be attributed to ongoing political instability, poverty, ethnic caste systems, and climate risks, which have been exacerbated by the COVID-19 pandemic. Countries with the highest prevalence of modern slavery in Africa are Eritrea, Mauritania, and South Sudan. According to the Global Slavery Index, Africa Regional Report 2023,[1] there are about 7 million people in modern slavery in Africa, with an estimated prevalence of 32 per 1,000 inhabitants in Mauritania.

DEMOGRAPHY OF MAURITANIA

The infant mortality rate in Mauritania was 185 per 1,000 in 1950 and has decreased to 29 per 1,000 live births by 2024. During the same period, the deaths under age 5 fell from 310 to 36 per 1,000 live births. As a result, Mauritania's population has grown from 700,000 in 1950 to more than 5 million by 2024, a more than sevenfold increase in three-quarters of a century.

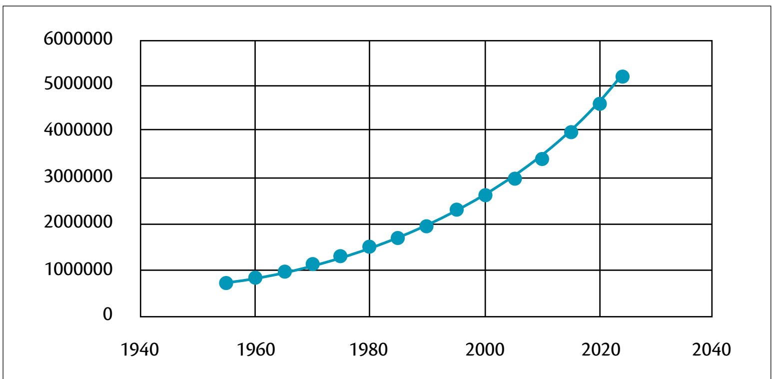

Figure 1: Population of Mauritania between 1955–2024 (https://www.worldometers.info/world-population/mauritania-population/ *Downloaded: 01.10.2024.)*

1 Walk Free: *Africa Regional Report 2023.*

It is expected that the rate of growth will be similar in the coming decades as well. Currently, the total fertility rate is 4.6 births/woman.

The gender and age distribution of the population in Mauritania is pyramidal. This is typical of countries with young and growing populations.

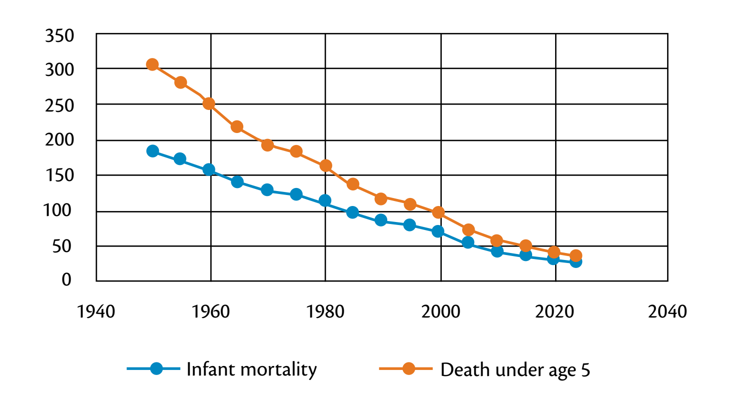

Figure 2: Infant and under age 5 mortality rates in Mauritania (per 1000 live births, 1950–2024) (https://www.worldometers.info/world-population/mauritania-population/, *Downloaded: 01.10.2024.)*

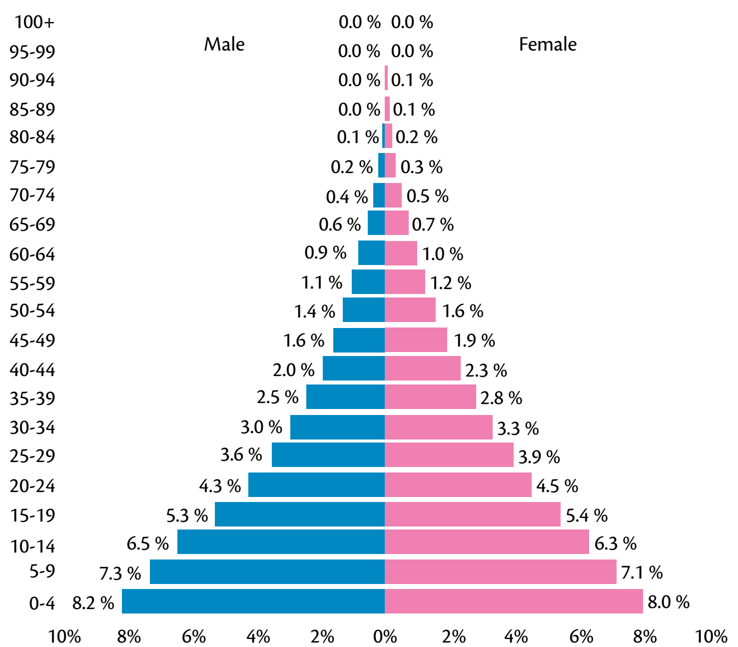

Figure 3: Population pyramid in Mauritania (2022) (https://www.populationpyramid.net/mauritania/2022/, *Downloaded: 10.01.2024.)*

HEALTHCARE SYSTEM

The organization of the public healthcare system in Mauritania is also pyramidal, with three levels:[2]

1. Operational level: This includes health posts and health centres.
2. Intermediate level: There are three types of hospitals: county hospitals, regional hospitals, and regional hospital centres.
3. Tertiary level: This consists of general and specialized hospitals.

The private healthcare sector is primarily concentrated in the capital and larger cities and has experienced significant development over the past 10 years.

Expensive medical treatments and surgeries remain out of reach for most residents. This is only minimally helped by projects implemented within the framework of aid programs, such as when King Salman Humanitarian Aid and Relief Centre volunteers performed 37 specialised and minimally invasive operations using the latest laparoscopic and robotic devices for heart surgery.[3] [4]

Traditional medicine practices are still widely accepted in Mauritania, there is no legal regulation in this regard.

The ratio of doctors to the population is 20 times lower than in the European Union (EU). There are only *0.2 doctors per 1,000 people* in Mauritania, compared to *4.3 per 1,000 people* on average in the EU (2018).[5]

The availability of hospital beds is 13 times lower than in the EU. In Mauritania, there are only 0.4 hospital beds per 1,000 people[6] (2006 – *No new data found.*) compared to 5.16 beds per 1,000 people on average in the EU[7] (2022). This was the case in 2006 when the country had only 3 million inhabitants. Since then, the population has increased by 70 percent and is still growing today. This rate may have lowered since then. If we look at the growth of the country's population (about 140,000 people per year), 50–60 new hospital beds would be required to maintain the 2006 level. The last hospital, the Nouadhibou Regional Hospital, was built in 2017 and has 250 beds.[8] In 2021, the construction of a new 300-bed hospital began with financial assistance from Saudi Arabia.[9] However, the limited availability of medical infrastructure significantly reduces access to high-quality healthcare for the population.

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2 *Plan National de Développement Sanitaire 2021–2030,* 14–16.

3 Arab World Press: *King Salman Aid Centre Concludes Laparoscopic Heart Surgery Project in Mauritania.*

4 After the Cuban Revolution in 1959, Cuba sent doctors and medical personnel to developing countries in Africa, Latin America, and Oceania under a new health program. These missions have had a significant positive local impact on the populations affected. In fact, doctors and medical personnel have become Cuba's "exports" over the years. Based on a previous agreement between the two countries, some sixty Cuban doctors and health technicians have been working in a hospital in Nouadhibou since 2017.

5 The World Bank Group: *Health Nutrition and Population Statistics.*

6 The World Bank Group: *Hospital beds (per 1,000 people) - Mauritania.*

7 Eurostat: *EU counted 2.3 million hospital beds in 2022.*

8 C.R.I.DE.M – Carrefour de la République Islamique de Mauritanie: *Nouadhibou: inauguration par le chef de l'état d'un hôpital des spécialités médicales.*

9 Saudi Gazette: *Saudi Arabia is building largest hospital in Mauritania.*

Picture 1: New medical centre in Atar by the Saudi Fund for Development (https://spa.gov.sa/_next/image?url=https%3A%2F%2Fportalcdn.spa.gov.sa%2Fbackend%2Foriginal%2F202312%2FrOpML7H2rUnaGyl7KNV34vqPFDszX06CCKyoFSqi.jpg&w=3840&q=75 *Downloaded: 01.10.2024.)*

Picture 2: Kaedi regional hospital constructed with local materials and skills (https://www.journeygourmet.com/continentes/Africa/Mauritania/Ka%C3%A9di/Ka%C3%A9di/imagenBig.jpg *Downloaded: 01.10.2024.)*

ENVIRONMENTAL RISK FACTORS

The climate in Mauritania is subtropic-desert, with hot and dry conditions prevailing in the central and northern regions. Rainfalls are extremely rare here, amounting to less than 30 millimetres annually. In the south, the climate transitions to a subtropical steppe, with the summer monsoon providing some rainfall between June and early October. Along the coast, sea breezes help moderate the heat, though the climate remains mild only in the

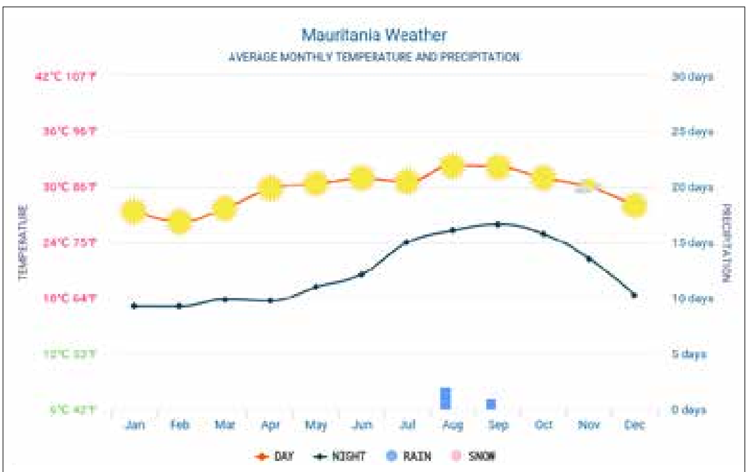


Figure 4: Mauritania weather – average monthly temperature and precipitation (https://hikersbay.com/climate/mauritania?-lang=en *Downloaded: 25.10.2024.)*

northernmost part, influenced by cool sea currents.

Mauritania is a "climate change sensitive" country. The trend of global warming contributes to several natural disasters such as drought, flooding, and deforestation in the region. This situation is further aggravated by population displacement, increasing urbanization, rising temperatures, prolonged heatwaves, increased variability in precipitation, higher evaporation rates, and an uneven geographic distribution of rainfall. These factors exacerbate the country's existing poverty by worsening conditions in water-dependent sectors such as agriculture and livestock.[10]

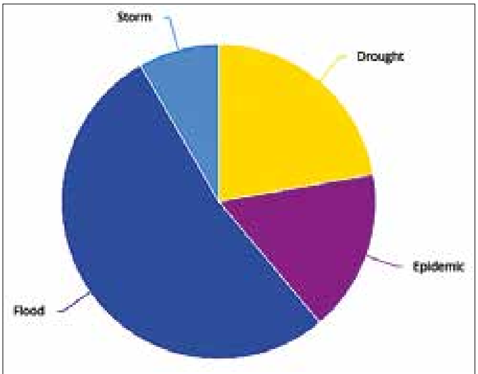
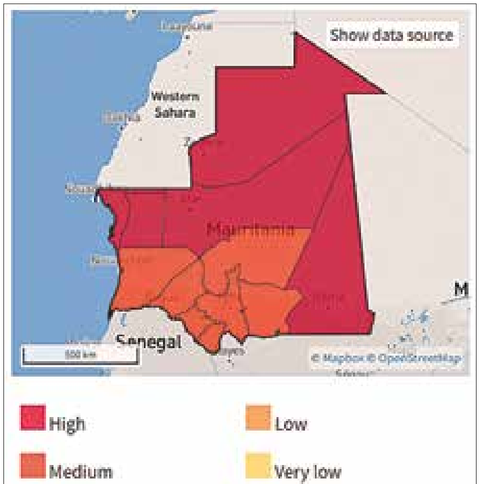


Figure 5: Average annual hazard occurrence for 1980–2020
(https://climateknowledgeportal.worldbank.org/country/mauritania/vulnerability#:~:text=While%20Mauritania%20is%20prone%20to%20drought%20and%20flooding,to%20agricultural%20lands%20as%20well%20as%20human%20health *Downloaded: 15.10.2024.)*

Mauritania faces a severe shortage of water resources. Fresh (and clean) water is a luxury, as the population only has 20 litres of water per person available for daily consumption. Low rainfall and high temperatures in urban areas result in increased salinity and pollution of water sources, leading to diarrheal diseases associated with contaminated water.



Map 1: Hazard levels of water scarcity in Mauritania
(https://thinkhazard.org/en/report/159-mauritania/DG *Downloaded: 28.10.2024.)*

The country's largest river, located on the southern border, is the Senegal River. According to a 2018 study, in the capital "only 26% of households had

10 Anta, Ndoye et al.: *Can Mauritania Reduce the Impact of Climate Disasters on its Economy.* "Climate-related natural disasters are becoming more frequent and severe in Mauritania, exacerbating long-standing challenges like land and infrastructure degradation, water stress, and food insecurity."

access to safe drinking water sources, while 70% of the population had access to improved latrines. The situation in rural areas is even worse."[11]

HEALTH RISK FACTORS

The leading causes of death per 100,000 inhabitants in Mauritania are listed in the graph below. Mauritania has a high burden of both communicable (such as malaria, tuberculosis, HIV/AIDS) and non-communicable diseases. According to the World Health Organization (WHO), "Mauritania's coverage rates of vaccination in children have historically been below the 90% target rate".[12]

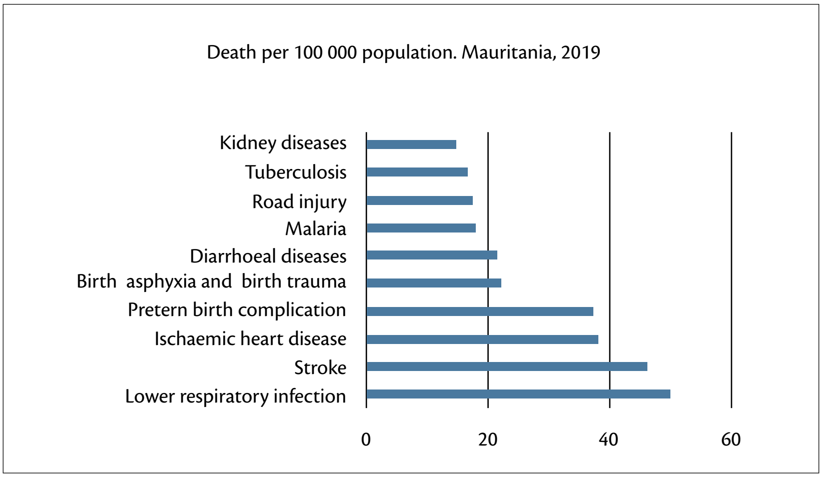


Figure 6: Top causes of death
(https://data.who.int/countries/478#:~:text=The%20top%20ten%20causes%20of%20death%20are%20statistical%20estimates%20based *Downloaded: 16.10.2024.)*

INFECTIOUS DISEASES

The country's climatic, hygienic, and epidemiological conditions are significantly different from those in East-Central European countries. Adequate medical care, comparable to East-Central European countries, is not ensured.

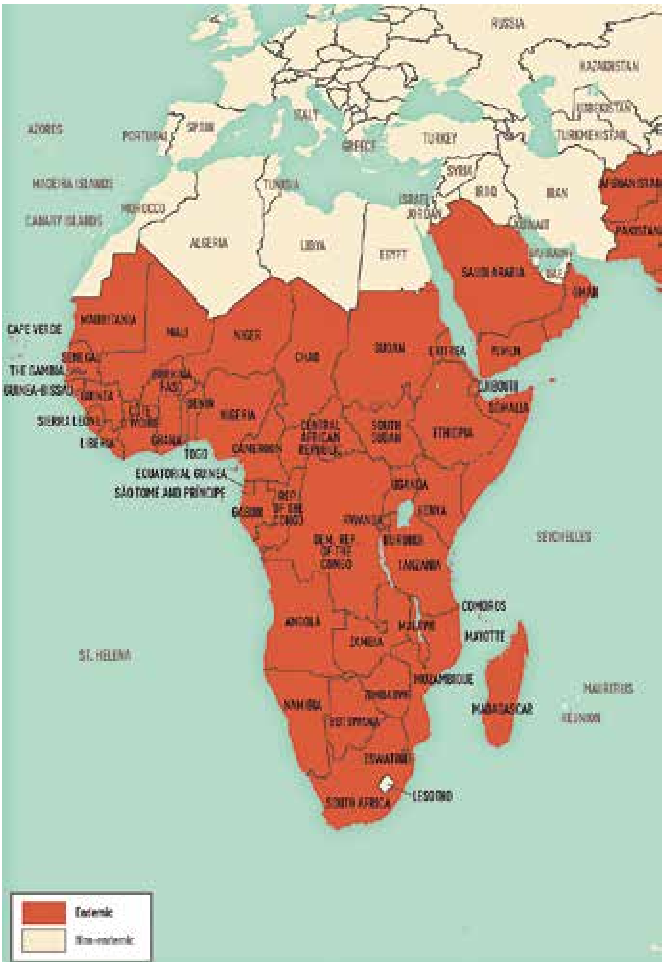
Based on the probability of occurrence and severity of hazard, the risk levels of diseases in Mauritania can be categorized as follows:
- *Low risk:* infrequent, mild illnesses.
- *Moderate risk:* endemic but mild infections.

11 Mohamed, Lemine Cheikh Brahim Ahmed et al.: *Hospitalizations and Deaths Associated with Diarrhea and Respiratory Diseases among Children Aged 0–5 Years in a Referral Hospital of Mauritania.*
12 WHO: *Country Disease Outlook, Mauritania.*

- *Significant risk:* infections that cause outbreaks of severe illness.
- *High risk:* unavoidable, potentially fatal diseases.

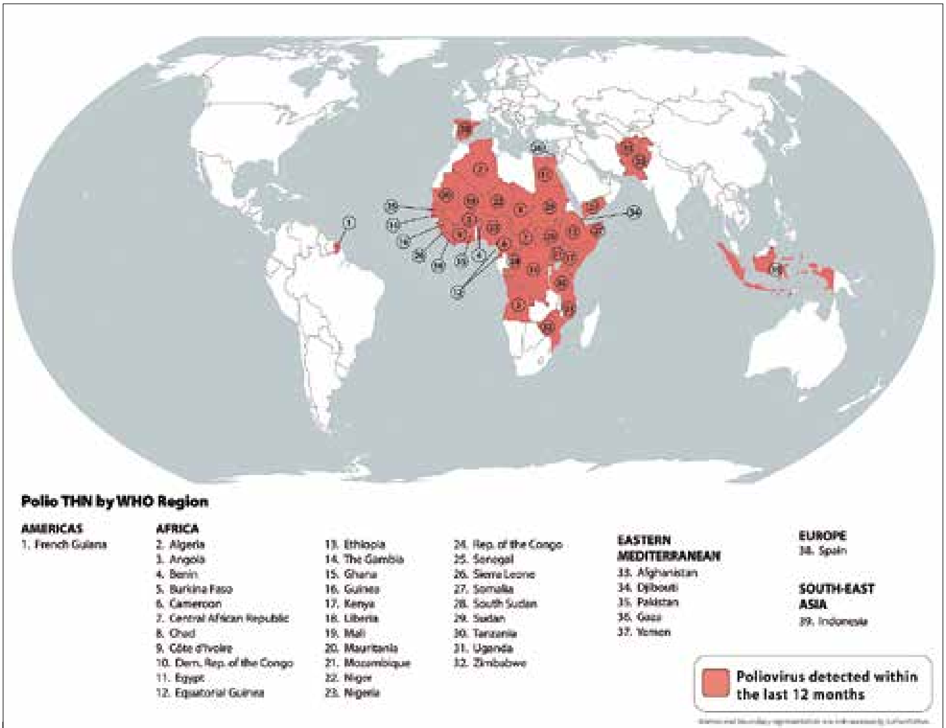
Without the aim of being exhaustive, here is a summary of the most common infectious diseases in Mauritania.

Malaria is a high risk in Mauritania. It is a vector-borne disease, in humans caused by protozoan parasites, which are transmitted by the bite of an Anopheles mosquito. Occasionally, transmission occurs by blood transfusion, needle sharing, etc. Malaria transmission occurs in large areas of Africa. According to the World Health Organization's World Malaria Report 2023,[13] "Globally in 2022, there were an estimated 249 million malaria cases in 85 malaria



Map 2: Malaria-endemic destinations in Africa & the Middle East (https://wwwnc.cdc.gov/travel/content/images/yellowbook/2024/_504_MAP_5-_13_Malaria-_endemic_destinations_in_Africa_the_Middle_East.jpg, *Downloaded: 20.10.2024.)*

13 WHO: *World Malaria Report 2023.*



*Map 3: Poliovirus detected within the last 12 months (*https://wwwnc.cdc.gov/travel/images/polio-global-map.png *Downloaded: 20.10.2024.)*

endemic countries and areas. […] The WHO African Region, with an estimated 233 million cases in 2022, accounted for about 94% of cases globally." In 2021, Mauritania was estimated to have 85,030 malaria cases (18 cases per 1,000 population), resulting in 1,144 deaths.[14]

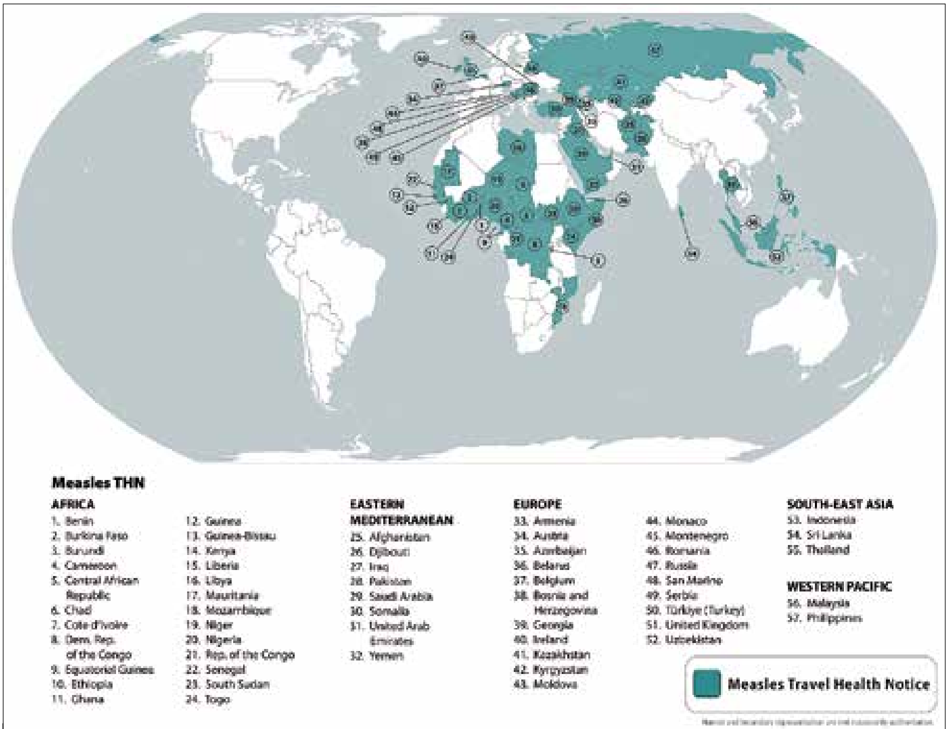
Malaria prevention consists of a combination of mosquito avoidance measures and chemoprophylaxis.

Poliomyelitis and measles have significant risks. In August 2024, there was a polio outbreak in Mauritania. Vaccine-derived poliovirus is circulating in many countries in the world. Mauritania reported an increased incidence of measles in September 2024. The transmission is high in some countries worldwide.

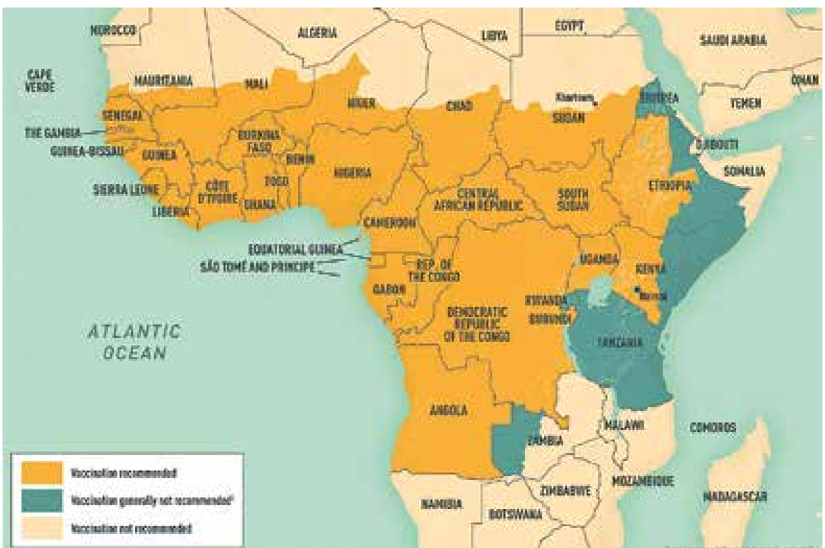
Preventive measure: a highly effective and well-tolerated vaccine is available against polio and measles.

Yellow fever has moderate risk in Mauritania. It is a vector-borne disease transmitted by the bite of an infected mosquito, primarily Aedes or Haemagogus spp. Yellow fever occurs in Sub-Saharan Africa and tropical South America, where it is endemic and intermittently epidemic. Vaccine against yellow fever is recommended for travellers over 9 months old to areas south of the Sahara Desert.

14 WHO: *Country Disease Outlook, Mauritania.*



*Map 4: Countries in the world with reported measles outbreaks (*https://wwwnc.cdc.gov/travel/images/measles_global_map.png *Downloaded: 20.10.2024.)*



*Map 5: Yellow fever vaccine recommendations for Africa (*https://wwwnc.cdc.gov/travel/content/images/yellowbook/2024/_465_MAP_5-_10_Yellow_fever_vaccine_recommendations_for_Africa1_2.jpg *Downloaded: 20.10.2024.)*

Overall, public health and epidemiology risks are significant in Mauritania. The table below lists the recommended vaccinations for the country.

Table 1: *Recommended vaccinations for Mauritania*

Vaccination	Regimen for primary immunisation	Earliest time of deployability (in exceptional cases)	Duration of immunity
Diphtheria **Pertussis** **Tetanus** Note: For management of a tetanus-prone wound, a dose of Boostrix or Adacel Polio may be administered if at least 5 years have elapsed since the previous receipt of a tetanus-containing vaccine. (Boostrix) **Polio** (Adacel Polio)	1 dose		10 years
Hepatitis A (Havrix 1440)	2 doses 0, 6–12 months	14 days after the first dose	20 years
Hepatitis B (Engerix B)	3 doses 0, 1, 6 months 4 doses 0, 1, 2, 12 months	after the third dose	The need for a booster dose in healthy individuals who have received a full primary vaccination course has not been established.
Measles **Mumps** **Rubella** **MMR**	1 dose	14 days after vaccination	lifelong
Seasonal influenza	1 dose	14 days after vaccination	1 season
Tick-bone encephalitis (TBE)	3 doses 0, 1–3, 9–12 months	14 days after the second dose	3 years
Rabies (Verorab) Note: After exposure, post-exposure prophylaxis must be ensured also for previously vaccinated persons on days 0 and 3!	3 doses 0, 7, 21–28 days	after the third dose	After basic immunisation, initial protection: 2 years. After each boost: 5 years
Yellow fever (Stamaril)	1 dose	10 days after vaccination	lifelong
Typhoid (Typhim VI)	1 dose	14 days after vaccination	3 years
Meningococcal Meningitis ACWY (Menactra) Note: Menactra can be used between the ages of 9 months and 55 years.	1 dose		4 years if one has a high risk of meningococcal infection
Chemoprophylaxis			
Malaria (Doxycycline)	The daily dosage for adults is 100 mg. The drug is started 1–2 days before traveling and finished 4 weeks after traveling.		

SUMMARY

In summary, Mauritania faces a wide range of challenges. The healthcare system struggles to keep pace with the population growth. Global warming, which is affecting the region and Mauritania, is expected to have increasingly serious consequences. Desertification is increasing, causing further economic damage and increasing poverty among the population. Access to drinking water is already critical and, in addition to vector-borne diseases, the spread of food- and water-borne infections is a major challenge. The question remains how long the current political stability will endure and whether it can effectively control or resolve these pressing issues.

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MAURITÁNIA EGÉSZSÉGÜGYI FELDERÍTÉSE

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KULCSSZAVAK egészségügyi ellátás, kockázatértékelés, fertőző betegségek, egészségügyi felderítés

ABSZTRAKT *A cikk célja, hogy ismertesse azokat a közegészségügyi és járványügyi kockázatokat, amelyek Mauritániára jellemzőek. Áttekinti azokat a tényezőket, amelyek az adott régióra és országra jellemzőek, de eltérnek az európaitól. Elemzi a demográfiai adatokat, az egészségügyi rendszer sajátosságait, a környezeti kihívásokat, amelyek hozzájárulhatnak a fent említett kockázatok kialakulásához.*

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