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Human enhancement from a military perspective – WHY, WHAT and HOW?

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Military conflicts have shifted from physical dominance to cognitive and technological enhancements, raising ethical, social and legal concerns. This article explores WHY they are pursued, WHAT enhancements are sought and HOW they are feasible, considering the associated implications.

1. Fundamental considerations

Military operations under international bodies such as the UN, NATO or the EU involve varied conditions. Enhancements, such as the use of Modafinil® by US personnel, raise ethical and legal issues due to potential adverse effects such as prolonged recovery and aggression. Alternatives like training or meditation and competing technologies like robotics also necessitate careful evaluation. For example, US military personnel use Modafinil® to promote wakefulness during tasks requiring sustained attention, while German forces can only use it with a prescription for specific medical reasons.[1]

1.1 Interlinked overview

1.1.1 On the necessity of distinguishing nuanced terms of use for enhancement and optimisation in military applications

The discourse surrounding human augmentation in military, defence and security applications is becoming increasingly nuanced, reflecting the rapid ad-

[1] Erley, Oliver M./Vergin, Annika/Haggenmiller, Christian/Sammito, Stefan: Human Enhancement – alter Wein in neuen Schläuchen oder tatsächlich eine Herausforderung für die Wehrmedizin? 2019. https://wmm.pic-mediaserver.de/index.php?f=artikel&a=201910_originbalarbeit, pp. 375-380, accessed 21 April 2024.

vancements in technology and the ethical considerations they entail.[2] Within this multifaceted landscape, the differentiation between enhancement and optimisation emerges as a pivotal concern. Understanding and delineating these concepts are paramount for several reasons:[3]

- **Ethical and moral imperatives**: the ethical implications of augmenting certain individuals' capabilities while others remain unaltered necessitate careful consideration. Differentiating between enhancement and optimisation is essential to address fairness in military operations, especially regarding equality. Informed consent is crucial, with individuals needing to understand the risks and benefits associated with each approach. Ensuring no individual or group within the military is unfairly disadvantaged or placed at significant risk is vital to maintain moral integrity and trust in augmentation

[2] DCDC, UK Ministry of Defence: Human Augmentation – The Dawn of a New Paradigm. 2020. https://www.gov.uk/government/publications/human-augmentation-the-dawn-of-a-new-paradigm, accessed May 2024; Ministry of Defence: Human-Machine Teaming. 2020. https://assets.publishing.service.gov.uk/media/5b02f398e5274a0d7fa9a7c0/20180517-concepts_uk_human_machine_teaming_jcn_1_18.pdf, accessed 26 June 2024; Puscas, Ioana M.: *Military Human Enhancement*. In: W. H. Boothby (ed.). New Technologies and the Law in War and Peace. Cambridge: Cambridge University Press, pp. 182-229. 2018.

[3] Various comprehensive sources provide valuable insights as a basis for the overview outlining the different concepts: see Harrison Dinniss, H. A./Kleffner, J. K.: Soldier 2.0: Military Human Enhancement and International Law. International Law Studies. 94, accessed 26 June 2024. 2018, pp. 163-205 https://digital-commons.usnwc.edu/cgi/viewcontent.cgi?article=1695&context=ils; NATO Science & Technology Organization. (n.d.): Neuroenhancement in Military Personnel: Conceptual and Methodological Promises and Challenges (STO-TR-HFM-311). Belgium: NATO STO. Retrieved from https://www.sto.nato.int/publications/STO%20Technical%20Reports/STO-TR-HFM-311/$TR-HFM-311-Pre-Release-ALL.pdf, accessed May 2024; NATO Science & Technology Organization. (n.d.). Biotechnology, Human Enhancement and Human Augmentation: A Comprehensive Overview of Its Topical Content (STO-TR-HFM-ST-335). Belgium: NATO STO. https://www.sto.nato.int/publications/STO%20Technical%20Reports/STO-TR-HFM-ST-335-A/$TR-HFM-ST-335-A-ES.pdf, accessed May 2024; Puscas, Ioana M.: Military Human Enhancement. In: W. Boothby (Ed.), New Technologies and the Law in War and Peace. Cambridge: Cambridge University Press. 2018, pp. 182-229:

policies. Ethical principles, such as proportionality and informed consent, are essential to responsibly manage these concerns.[4]

- **Strategic and tactical significance**: military organisations must balance resources between augmenting capabilities and optimising existing systems and personnel. Distinguishing between enhancement and optimisation guides strategic decisions, aligning priorities with operational contexts to maximise mission success and effectiveness.
- **Societal and legal implications**: transparent communication concerning military augmentation is crucial for public trust. Differentiating enhancement from optimisation informs legal frameworks and regulations, ensuring responsible technology use while safeguarding individual rights.

Elucidating the distinction between enhancement and optimisation is paramount in the discourse on human augmentation in military applications. By comprehensively understanding each approach's nuances, military stakeholders can navigate the ethical, strategic and societal dimensions of human augmentation with greater clarity and foresight.

1.1.2 The three pillars of the human-as-a-platform model[5]

Conceptualising the human-as-a-platform is fundamental to understanding the potential impact and limitations of human augmentation approaches and identifies three main areas:

[4] Whetham, David/Purves, Duncan/Nericcio, Lorenzo et al.: Ethical Human Augmentation in the Military - A Comparison and Analysis of National and International Frameworks, Regulation, and Approval Processes. 20 July 2022. Preprint (Version 1) available at Research Square. https://doi.org/10.21203/rs.3.rs-1826964/v1, accessed 29 June 2024.

[5] UK Ministry of Defence: Development, Concepts and Doctrine Centre (DCDC): Human Augmentation – The Dawn of a New Paradigm. 2020. https://www.gov.uk/government/publications/human-augmentation-the-dawn-of-a-new-paradigm, accessed 17 May 2024.

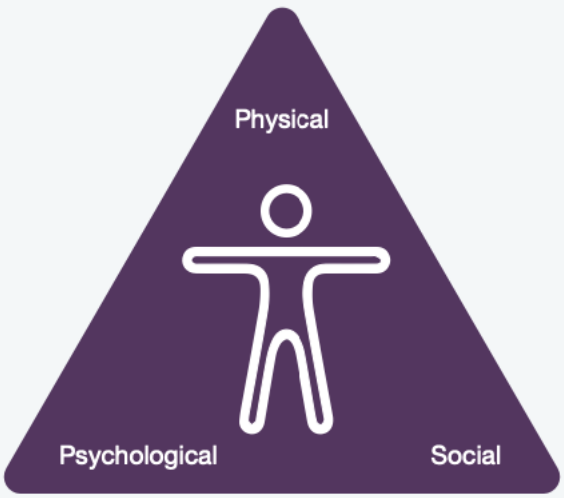

Figure 1: The human-as-a-platform model.[6]

- **Physical performance**: involves navigating and engaging with the physical environment. Key attributes include strength, dexterity, speed and endurance, with technologies such as exoskeletons enhancing these capabilities.
- **Psychological performance**: focuses on cognition, emotion and motivation, highlighting the interplay of mental processes, emotional states and behavioural drivers. Strategies such as targeted training and cognitive enhancers optimise cognitive functions.[7]
- **Social performance**: emphasises interpersonal, group and societal dynamics, and collaborative efforts. Skills such as communication, empathy and teamwork are crucial, with leadership training and com-

[6] UK Ministry of Defence: Development, Concepts and Doctrine Centre (DCDC): Human Augmentation – The Dawn of a New Paradigm. 2020, p. 12. https://www.gov.uk/government/publications/human-augmentation-the-dawn-of-a-new-paradigm, accessed 17 May 2024.

[7] For more details, see Grinschgl, Sandra: Cognitive enhancement – A critical reflection from psychology and neuroscience. In chapter MEDICINE in this publication. Grinschgl explains that the scientific evidence for psychological enhancement via medication is currently not very promising. One of the reasons for this is that many relevant drugs have been developed for disease states.

munication technologies fostering team cohesion and enhancing social performance.[8]

1.1.3 Bringing it all together OR introducing the conceptional framework for human augmentation analysis

Building on the human augmentation spectrum differentiation and the human-as-a-platform model, our conceptual framework introduces a novel approach to analysing human augmentation technologies and their military applications. By considering the degree of change, invasiveness and target area, our framework offers a thorough understanding of these technologies. It uses a three-axis model for a comprehensive analysis:

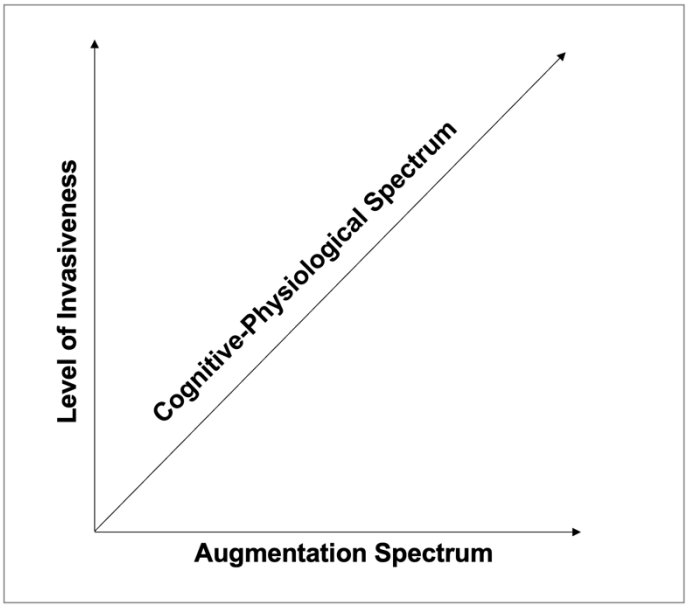

Figure 2: Human augmentation analysis framework. Source: Authors.

[8] UK Ministry of Defence: Development, Concepts and Doctrine Centre (DCDC): Human Augmentation – The Dawn of a New Paradigm. 2020. https://www.gov.uk/government/publications/human-augmentation-the-dawn-of-a-new-paradigm, accessed 17 May 2024.

- **Augmentation Spectrum** (X-axis): represents the degree of change, from *optimisation* (refining existing capabilities) to *enhancement* (fundamentally altering human potential).
- **Invasiveness** (Y-axis): reflects the level of physical intrusion, from non-invasive (e.g. wearables) to highly invasive (e.g. neural implants).
- **Cognitive-Physiological Spectrum** (Z-axis): distinguishes between technologies targeting cognitive functions (e.g. memory, decision-making) and physiological functions (e.g. strength, endurance).

Visualising human augmentation technologies within a three-dimensional framework allows for thorough analysis, moving beyond a binary view. This approach is invaluable for assessing military applications, considering ethical and practical implications across various dimensions.

1.2 Definitions and terms

1.2.1 Human performance augmentation and enhancement

To clearly define human optimisation options, it is essential to differentiate between augmentation and optimisation.

Human (performance) augmentation

Human performance augmentation refers to using science and technology to temporarily or permanently improve human performance.[9] This concept bridges technology-centred human-machine interactions.[10]

[9] Planungsamt der Bundeswehr: Human Augmentation – Die Verbindung von Mensch und Maschine. 2021. https://www.bundeswehr.de/de/organisation/weitere-bmvg-dienststellen/planungsamt-der-bundeswehr-/human-augmentation-verbindung-mensch-maschine-planungsamt-5016384, accessed 7 April 2024.

[10] Idem.

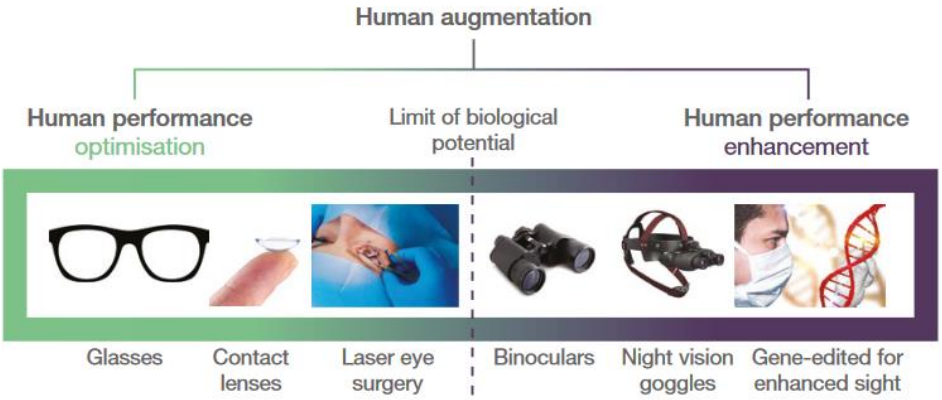

Figure 3: Human performance enhancement (HPE) within the spectrum of human augmentation.[11]

Human performance optimisation (HPO)

HPO involves measures to develop or maintain individual performance, especially when natural abilities are compromised. It focuses on optimising capabilities up to biological limits, such as using an implanted knee joint to restore movement or correcting defective vision.[12]

Human enhancement (HE) or human performance enhancement (HPE)

HE or HPE encompasses all measures that extend performance beyond the individual's maximum potential. This involves physical and/or psychological, but also sensory or cognitive capabilities ("super-human capabilities"). It also includes measures that uncover new characteristics, e.g. new sensory

[11] UK Ministry of Defence: Development, Concepts and Doctrine Centre (DCDC): Human Augmentation – The Dawn of a New Paradigm. 2021, p. 18. https://www.gov.uk/government/publications/human-augmentation-the-dawn-of-a-new-paradigm, accessed 28 April 2024.

[12] Planungsamt der Bundeswehr: Human Augmentation – Die Verbindung von Mensch und Maschine. 2021. https://www.bundeswehr.de/de/organisation/weitere-bmvg-dienststellen/planungsamt-der-bundeswehr-/human-augmentation-verbindung-mensch-maschine-planungsamt-5016384, accessed 7 April 2024.

abilities through implants. HE measures can be subdivided into the following categories:[13]

- **Biochemical approaches**: pharmacological, nutrition-based and genetic performance enhancements.
- **Non-invasive approaches**: transcranial stimulation, exoskeletons, augmented reality, silent speech interface systems.
- **Invasive methods:** smart drugs, invasive brain stimulation or brain-computer interfaces.
- **Biomonitoring methods**

Human (performance) enhancement in the military

The use of human enhancement (HE) in the military raises key questions about its integration and systematic definition. HE is defined as any improvement that enhances soldiers' capabilities beyond the standard performance levels required for their roles. These standards are typically measured through fitness criteria and performance metrics. HE is considered when capabilities surpass natural limits, focusing on average performance rather than individual extremes. This approach is aimed at systematically applying biological and technical solutions to boost military performance and operational capability, rather than creating "super soldiers".

It should not be overlooked that the demand for and potential of HE is heavily dependent on the respective field of application. A military pilot operates in a different environment than an engineer or infantryman. In each case, there are different requirements and challenges with regard to what appears accessible and sensible for optimisation in the three dimensions of the physical, psychological and social. From a military perspective, their strategic integration into the overall organisation is crucial.[14]

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[13] Erley, Oliver M./Vergin, Annika/Haggenmiller, Christian/Sammito, Stefan: Human Enhancement – alter Wein in neuen Schläuchen oder tatsächlich eine Herausforderung für die Wehrmedizin? 2019, pp. 375-380. https://wmm.pic-mediaserver.de/index.php?f=artikel&a=201910_originbalarbeit, accessed 21 April 2024.

[14] See Kunze, Michael/Harbich, Harald: Human Enhancement –biological-neurological aspects from a military perspective. In chapter MEDICINE in this publication.

Moreover, human performance optimisation (HPO) and HE can also address performance issues at the lower end of military capability. For example, as the number of unfit individuals increases, enhancing performance to meet minimum thresholds can improve team cohesion. This concept is known as human performance degradation (HPD), where enhancements help manage or mitigate declines in performance.

Human performance degradation (HPD)

HPD describes performance decline due to stress or tactics aimed at impairing an adversary's capabilities,[15] such as contaminating supplies to impair the enemy's performance.[16] Conversely, it can be used positively to manage hyperactivity, such as treating ADHD to enhance collaboration within a military team.

1.2.2 Humans and technology

One area not to be neglected is the realm of optimisation or enhancement of human capabilities closely intertwined with technology, machinery and artificial intelligence, with particular regard to social, ethical and legal questions of responsibility.

Human-machine teaming (HMT)

Human-machine teaming (HMT) blends human and machine capabilities to enhance collaboration through continuous mutual learning. Artificial intelligence in this context augments human abilities rather than replacing them.

Manufacturing has embraced collaborative robots, or cobots. These machines work alongside human workers, enhancing productivity and safety on the factory floor. Robots can perform repetitive and physically demanding

[15] Ibid.

[16] Such tactics should be mentioned as they are ancient. The use of HPD tactics in a modern setting must be subject to rigorous legal, ethical and political scrutiny.

tasks, allowing humans to focus on more skilled and creative aspects of production.[17]

In the military, the British Army is pioneering the integration of humans with Robotics and Autonomous Systems (RAS). These systems, supported by robust networks, work within Human-Machine Teams to provide data for faster, better decision-making. Soldiers are equipped with digital skills to understand and trust these systems, even as the number of human soldiers decreases in favour of more numerous and cost-effective platforms that enhance combat effectiveness while reducing risk.[18]

As technology and AI advance, there are concerns surrounding diminishing human roles in decision-making. However, maintaining "human-in-the-loop" (HITL) or "human-on-the-loop" (HOTL) systems remains crucial for legal and operational reasons. Even with fully automated systems, human oversight is essential, and optimising these roles can enhance overall system performance.

Machine enhancement

Machine enhancement focuses on optimising machines to better meet human needs, contrasting with human augmentation, which improves human capabilities for better machine interaction.
As technology advances, including AI and self-learning systems, the role of humans in these interactions remains critical for decision-making and legal responsibility, even as systems become more automated.

1.3 Individual and collective interdependence

From a military perspective, optimising soldiers involves enhancing individual strengths and specialisations. However, cohesive teamwork often outweighs individual performance. Leaders must balance individual and team skills, both physical and cognitive ones, to ensure that no member becomes a liability. Decisions on human enhancement should reflect these priorities.

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[17] Ewell, Russ: The Human-AI Collaboration: How Humans and Machines Are Working Together. 2023. https://www.infineon.com/cms/en/discoveries/human-machine-interaction/, accessed 7 April 2024.

[18] The British Army: Our Future. Human Machine Teaming. 2023. https://www.army.mod.uk/our-future/modernise/human-machine-teaming/, accessed 7 April 2024.

1.4 HPE challenges for the military[19]

In a military context, biomedical and technological interventions aimed at enhancing individuals' physical or cognitive abilities beyond their natural limits present both opportunities and ethical challenges.

One central dilemma lies in the question of voluntariness and human dignity. The obligation to undergo such enhancements could undermine soldiers' personal autonomy and introduce a new form of coercion. Additionally, access to these technologies could trigger an arms race between nations, where technological superiority takes precedence over diplomacy and disarmament.

Moreover, there are health and societal risks associated with human enhancement.

The long-term health effects of these technologies are often unclear, posing risks to both physical and mental well-being. Furthermore, the introduction of enhancements could lead to a two-tiered society, where enhanced and non-enhanced individuals are treated differently.

Against this backdrop, the international community faces the challenge of developing clear rules and standards for the use of human enhancement within the military. Without proper regulation, human rights could be jeopardised, and global stability and security could be compromised. Careful consideration of the opportunities and risks, as well as an international consensus on ethical and regulatory frameworks, is therefore essential to manage and mitigate the long-term consequences of such technologies.

[19] Lin, Patrick: More Than Human? The Ethics of Biologically Enhancing Soldiers. *The Atlantic*, 17 February 2012. https://www.theatlantic.com/technology/archive/2012/02/more-than-human-the-ethics-of-biologically-enhancing-soldiers/253217/.

2. The questions of WHY, WHAT and HOW regarding human enhancement in the military

2.1 WHY human enhancement in the military?

Human enhancement in the military aims to improve operational effectiveness, enhance survivability and maintain a competitive edge. This is driven by the need to adapt to evolving threats and maximise the potential of military personnel.

2.2 WHAT areas can and should be optimised?

Human enhancement in the military can target **physical**, **psychological (cognitive and sensory)** and **social** components. Physical improvements include power, speed, endurance and coordination skills. Psychological optimisation focuses on decision-making, reaction times, resilience and sensory perception. Social enhancements improve teamwork, communication and leadership. Together, these lead to better mission execution and overall performance.

2.3 HOW does the military intend to achieve human enhancement?

The military plans to achieve human enhancement through advanced research and development, integrating new technologies and specialised training programmes. This includes exploring genetic modifications, cognitive enhancers and biomechanical augmentations.

3. Possibilities for optimising abilities through human enhancement

Building on this framework, various methods of HPE/HPO are presented below. The optimisation of human abilities for military performance requires a comprehensive approach that addresses physical, psychological and social dimensions.

3.1 Physical enhancement

Furthermore, the positive impact of physical activities or exercise on cognitive performance complicates the distinct organisational categorisation of human enhancement (HE) measures. Hence, we will initially examine general overlapping areas, and subsequently, where feasible, furnish specific categorisations.

3.1.1 Generalities

Enhancing military physical capabilities involves using purpose-driven tools such as exoskeletons. These devices, designed to be lightweight yet durable, boost lifting, carrying, speed and jumping abilities while offering protection and maintaining mobility. Key factors include seamless human-machine interaction, comfort and reliable energy supply.

Exoskeletons,[20] innovative wearable devices, enhance human mobility and strength. These external structures, designed to support the musculoskeletal system, come in two main categories: passive and active.

- **Passive exoskeletons**: unpowered, they reduce physical strain and injury risk by redistributing weight and supporting proper posture, beneficial in tasks such as heavy lifting and repetitive motions.
- **Active exoskeletons**: powered, they interpret neural signals or amplify natural movements, restoring mobility for disabled individuals and enhancing strength and endurance for able-bodied users. They are used in rehabilitation, industrial and military applications.[21]

[20] UK Ministry of Defence: Development, Concepts and Doctrine Centre (DCDC): Human Augmentation – The Dawn of a New Paradigm. 2021. https://www.gov.uk/government/publications/human-augmentation-the-dawn-of-a-new-paradigm, accessed 28 April 2024.

[21] Idem.

Pharmacological enhancement: substances that affect alertness, concentration, attention or memory, e.g. methylphenidates (e.g. Ritalin) or amphetamine salts such as Adderall[22]

Prosthetics and implants:[23] technological advancements in physical enhancements include prosthetics, joint replacements, artificial lenses, cochlear implants, dental implants, pacemakers, brain stimulators and plastic surgery implants. These innovations address physical limitations and improve body functionality.

Human biomonitoring:[24] wearable sensors to track fitness, stress and physiological metrics. It enables personalised feedback and adjustments through training, pharmaceuticals or human-machine interface improvements.

Biosensors, wearable biomedical systems:[25] over the next two decades, advanced systems will monitor soldier health in real time, detecting biomarkers for CBRN agent exposure, disease management and biomedical research.

Optogenetic bodysuit sensor web:[26] this emerging technology offers sensory feedback for muscle control, potentially enhancing physical performance within 20 years.

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[22] For more on this, see Grinschgl, Sandra: Cognitive enhancement – A critical reflection from psychology and neuroscience. In chapter MEDICINE in this publication. Grinschgl refers to the fact that both long-term risks and side effects have not been sufficiently explored. In addition to ethical considerations, both must be carefully evaluated before any use can even be considered.

[23] Schuster, Inge: Transhumanismus - der Mensch steuert selbst seine Evolution. 2019. https://scienceblog.at/transhumanismus-der-mensch-steuert-selbst-seine-evolution, accessed 28 April 2024.

[24] NATO: Science and Technology Trends 2023-2043 – Across the Physical, Biological, and Information Domains. 2023 pp. 63 and 69. https://www.nato.int/nato_static_fl2014/assets/pdf/2023/3/pdf/stt23-vol2.pdf, accessed 28 April 2024.

[25] Ibid., pp. 63 and 89; for more on this see Kunze, Michael/Harbich, Harald: Human Enhancement –biological-neurological aspects from a military perspective. In chapter MEDICINE in this publication.

[26] Ibid., 64.

Implanted chips for monitoring and identification:[27] implanted chips monitor health and identity, issuing alerts for timely interventions and facilitating secure environmental interactions.

Brain-computer interfaces (BCI):[28] allow individuals to control external devices using their brain activity, particularly in the cognitive area, as mentioned in point 2.2.2.

Detection and treatment of wounds:[29] AI-supported systems can improve wound detection and treatment, especially in high-demand environments, ensuring effective care and triage.

Below, individual aspects of physical capability optimisation are examined in detail.

3.1.2 Power and speed

Power and speed can be enhanced through training, mechatronic devices such as exoskeletons, nutrition and physical enhancement drugs. However, drugs such as stimulants and steroids often have serious side effects and limited applicability.[30]

3.1.3 Endurance

Increasing resilience and endurance involves various forms of endurance, including strength endurance and speed endurance. With regard to prolonged endurance performance, an optimally coordinated alternation be-

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[27] Idem.

[28] Vilela, Marco/Hochberg, Leigh R.: Applications of brain-computer interfaces to the control of robotic and prosthetic arms. 2020, pp. 87-99. https://www.sciencedirect.com/science/article/abs/pii/B9780444639349000081, accessed 28 April 2024.

[29] Chaichulee, Sitthichok/Chairat, Sawrawit et al.: AI-Assisted Assessment of Wound Tissue with Automatic Color and Measurement Calibration on Images Taken with a Smartphone. 2023. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9858639/, accessed on 3 May 2024.

[30] Shao, Shuyu/Wu, Jintao/Zhou, Qianxiang:Developments and Challenges in Human Performance Enhancement Technology. 2021. https://www.sciencedirect.com/science/article/pii/S2590093521000394, accessed 28 April 2024.

tween exertion and recovery phases is crucial. While stimulants such as caffeine to amphetamines and Modafinil® enhance endurance capacity for up to 40 hours,[31] sleep aids and tranquilisers are intended to promote more effective recovery. Studies showed that prolonged use carries more serious risks. These potential risks encompass the development of conditions such as arrhythmia, high blood pressure, and a compromised immune system.[32]

3.1.4 Coordination and Life Kinetik

Special methods, including Life Kinetik training, improve coordination, reaction speed and cognitive performance, enhancing movement techniques and athletic performance.[33]

3.1.5 Genetics

The exploration and application of genetic characteristics for enhanced performance are still in the development phase. This concept draws inspiration from elite sports, where genes of exceptional athletes are considered for gene therapy to enhance the performance of others.

CRISPR/Cas9 (clustered regularly interspaced short palindromic repeats)[34]

Germline engineering alters an organism's entire genetic makeup and is heritable, impacting future generations, whereas somatic modification targets specific cells, affecting only the treated individual. CRISPR/Cas9 technology

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31 Tovey, Mark: British troops 'kept awake on smart drugs': How MoD has spent up to £800,000 on more than 12,500 doses of controversial stimulant modafinil over the last eight years², in https://www.dailymail.co.uk/news/article-10707005/Thousands-smart-drugs-bought-MoD-soldiers-awake-40-hours-straight.html, accessed 28 April 2024.

32 Idem.

33 Komarudin, Komarudin/Awwaludin, Patriana Nurmansyah: Life Kinetik Training in Improving the Physical Condition of Football Athletes. 2019. In https://www.researchgate.net/publication/336722602_Life_Kinetik_Training_in_Improving_the_Physical_Condition_of_Football_Athletes, accessed April 2024.

34 UK Ministry of Defence: Development, Concepts and Doctrine Centre (DCDC): Human Augmentation – The Dawn of a New Paradigm. 2021, p. 95. https://www.gov.uk/government/publications/human-augmentation-the-dawn-of-a-new-paradigm, accessed 28 April 2024.

allows precise gene manipulation, achieving notable success in treating genetic disorders, such as a 2019 case where it addressed a lethal condition.

Genetic modification, including DARPA's pursuit of creating super soldiers with extraordinary abilities, offers significant potential for human enhancement. However, it also raises profound ethical and societal concerns, such as the blurring of moral boundaries, unequal access to enhancements and unintended consequences for human evolution.

3.2 Cognitive (psychological) enhancement

Beyond physical capabilities, cognition presents a vast realm for human performance optimisation (HPO) and enhancement (HPE). Derived from the Latin "cognition", meaning "knowledge", cognition encompasses all mental information processing processes. This includes perceptual and cognitive functions, both conscious and unconscious ones. Cognition involves the intake/perception, processing, storage and retrieval of information, with a focus on problem-solving skills and motivation.

3.2.1 Sensory (reception of the environment)

Commonly known as sensorics, this involves enhancing sensory perception across the **five senses (sight, hearing, touch, taste, smell)**, viewing humans as sensors interacting with their environment. Improvement in this area enables quicker and more comprehensive intake of information, complemented by optimised cognitive processing.

General and multi-sensor measures in human performance optimisation (HPO) and enhancement (HPE) are outlined, along with specific measures related to sight, hearing and touch. In a military context, taste and smell are not prioritised for HPO and HPE, as alternative solutions, such as technical or canine olfactory capabilities, are more suitable.

Sense of sight

In the visual area, the diversity of options provided by HPO and HPE is particularly evident. Consequently, only a selection can be presented here.

Ocular enhancements involve overlaying data streams onto a soldier's retinal wall, potentially expanding their vision beyond visible light. For instance, soldiers equipped with such implants might gain the ability to see objects within the infrared range, allowing them to detect hidden threats or navigate environments with low visibility, such as smoke-filled battlegrounds or dark subterranean areas.[35]

Cross Reality (XR)[36]

Cross Reality (XR) includes **Virtual Reality (VR)**, **Mixed Reality (MR)** and **Augmented Reality (AR).** Extended Reality (XR) encompasses Virtual Reality (VR), Mixed Reality (MR) and Augmented Reality (AR). In military aviation, XR has been used for years through head-up displays, helmet systems and flight simulators, with expanding applications due to reduced costs. VR is applied in education, medicine, gaming and entertainment, while AR is increasingly utilised in advertising and retail. In defence, VR is used for training, and AR improves situational awareness by overlaying information onto the real world. XR's utility is limited by energy, processing power, broadband speeds and data security. The UK's Royal Navy, for instance, uses AR glasses to enhance situational awareness and decision-making on frigate bridges, showcasing XR's impact on military operations.[37]

Cross Reality has emerged as game-changer, reshaping the landscape of military training, e.g.:[38]

- Immersive VR and AR simulate battlefields and enhance tactical readiness, decision-making and marksmanship.

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35 The National Interest, Task and Purpose: DARPA is Eyeing a High-Tech Contact Lens Straight Out of 'Mission: Impossible'. 2019. https://nationalinterest.org/blog/buzz/darpa-eyeing-high-tech-contact-lens-straight-out-mission-impossible-54617, accessed 28 April 2024.

36 UK Ministry of Defence: Development, Concepts and Doctrine Centre (DCDC): Human Augmentation – The Dawn of a New Paradigm. 2021, pp. 36f. https://www.gov.uk/government/publications/human-augmentation-the-dawn-of-a-new-paradigm.

37 Idem.

38 Proven Reality: 20+ Applications of VR and AR in Military Training. https://provenreality.com/virtual-reality/applications-of-vr-and-ar-in-military-training/, accessed 29 April 2024.

- AR aids target identification, tactical data overlay and cost-effective environmental and cybersecurity training.
- VR stress inoculation and AR fitness programmes prepare soldiers physically and psychologically.
- AI integration and wearable AR promise enhanced realism and battlefield awareness.

Neil Harbisson, a colour-blind artist, uses a head-mounted antenna with a colour sensor that converts colours into sounds, enhancing his perception. This showcases how technology can expand sensory capabilities, providing new modes of perception.[39]

Head-up displays (HUDs)[40]

Overlay targeting symbols on real-world targets, enhancing situational awareness and decision-making. These displays overlay targeting symbols on real-world targets, enhancing situational awareness and decision-making by providing vital information directly to the user's field of view.

In the near future, head-up displays will undergo further development with a focus on three key areas.

- Improvements in the power efficiency of micro-displays
- Advancements in optical fabrication techniques for free-form optical surfaces, and
- Integration and proliferation of smartphones and wireless data links.

Auditory sense

Auditory enhancements could protect soldiers from overexposure to loud noises while also increasing sensitivity to low-amplitude sounds. For example, soldiers with auditory implants might have the capability to detect faint sounds that could signal approaching danger or communicate discreetly with

[39] Donahue, Michelle Z.: Ein farbenblinder Künstler wurde zum ersten Cyborg der Welt. https://www.nationalgeographic.de/wissenschaft/2017/04/ein-farbenblinder-kuenstler-wurde-zum-ersten-cyborg-der-welt, accessed 29 April 2024.

[40] NATO: Science and Technology Trends 2023-2043 – Across the Physical, Biological, and Information Domains, 2023. p. 66, https://www.nato.int/nato_static_fl2014/assets/pdf/2023/3/pdf/stt23-vol2.pdf., accessed 28 April, 2024.

fellow soldiers using specialised frequencies. This heightened auditory perception could enhance situational awareness and communication on the battlefield, potentially saving lives in high-stress environments.[41]

The development of ocular and auditory implants could become feasible approximately 30 years from now.[42]

Sense of touch – Fine motor skills[43]

Fine motor skills are crucial in military tasks such as weapon handling, equipment operation and medical procedures. Stressors such as psychological pressure, physical fatigue and loud noises can impair these skills by causing brain overstimulation, concentration issues and anxiety.

Experience can mitigate stress impacts on fine motor skills, with seasoned personnel often showing better stress management, cognitive function under pressure and motor performance.

Understanding the interplay between stress, experience and fine motor skills is essential for developing effective training and support strategies. Tailored training and mental health support can enhance performance and safety. Further research is needed to better understand these relationships and improve training protocols.

3.2.2 Cognitive processes

Enhanced sensory perception should lead to improved cognitive function. Cognitive training, neurofeedback technologies and brain stimulation aid in enhancing cognitive performance in areas such as thinking, memory retrieval, learning, problem-solving and accelerated decision-making.

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41 U.S. Army Combat Capabilities Development Command Chemical Biological Center: Researchers Help DoD Consider Challenges of Human Enhancement. 2019. https://www.cbc.devcom.army.mil/newspost/researchers-help-dod-consider-challenges-of-human-enhancement/, accessed 28 April 2024.

42 Idem.

43 Stergiou, Maria/Aladro-Gonzalvo, Arian R./Tornero-Aguilera, José F. et al.: Influence of Combat Experience on Psychophysiological and Fine Motor Skill Responses in Air Force Warfighters under Acute Stress. 2023. https://revistamedicinamilitara.ro/wp-content/uploads/2024/01/RJMM-vol-CXXVII-nr-5-din-2024-part-1.pdf, accessed 29 April 2024.

Improvements have been observed in cognitive functions and procedural processes from transcranial stimulation, such as voluntary motor skills and memory. Long-term enhancements are achievable through device-based treatment and tailored training.[44]

Non-invasive methods for synaptic plasticity:[45] increase synaptic plasticity for improved cognitive performance and learning, supporting rapid and practical training of military personnel in complex tasks.

Decision-Making under Stress: Mixed Reality Applications for Cognitive Training:[46]

The U.S. Army's Synthetic Training Environment (STE) programme uses mixed reality technology to create immersive training environments. Soldiers engage in realistic scenarios that challenge cognitive abilities, such as decision-making under stress, enhancing their cognitive skills in simulated combat situations.

Commercialisation and accessibility:[47] consumer-grade EEG headsets, like those from NeuroSky, democratise access to neurofeedback technology, enabling users to monitor brain activity and engage in brain-controlled applications and games for cognitive enhancement. Neurofeedback therapy with tools such as MindReflector has shown significant improvements in PTSD symptoms among veterans, enhancing sleep, reducing irritability and improving concentration, thus enhancing their quality of life and relationships.

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44 Coffman, Brian A./Clark, Vincent P./Parasuraman, Raja: Battery powered thought: Enhancement of attention, learning, and memory in healthy adults using transcranial direct current stimulation. In: NeuroImage, Volume 85, Part 3, 15 January 2014, pp. 895-908, https://www.sciencedirect.com/science/article/abs/pii/S1053811913008550?via%3Dihub, accessed 12 August 2024.

45 Defense Advanced Research Projects Agency (DARPA): Boosting Synaptic Plasticity to Accelerate Learning. 2016. https://www.darpa.mil/news-events/2016-03-16, accessed 29 April 2024.

46 Novogradac, Michael M.: Soldiers test new synthetic training environment. 2024. https://www.army.mil/article/274266/soldiers_test_new_synthetic_training_environment, accessed 29 April 2024.

47 NeuroSky: Neurofeedback for Military Veterans with PTSD. 2017. https://neurosky.com/2017/09/neurofeedback-for-military-veterans-with-ptsd/, accessed 29 April 2024.

Neurological interfaces and brain-machine interfaces (BMIs) and direct neural enhancement:[48] BMIs record and stimulate brain activity to enhance brain function, including devices such as cochlear and retinal prostheses.

Brain-computer interfaces (BCIs):[49] BCIs translate brain activity into commands for controlling external devices, aiding individuals with severe motor disabilities in communication and interaction through neural activity recording and decoding.

Neuralink®:[50] founded by Elon Musk, Neuralink integrates brain waves with artificial intelligence to enhance cognitive capabilities and technological integration.

Cognition-enhancing drugs:[51]

Cognition-enhancing drugs, or nootropics, include substances like caffeine, nicotine, amphetamines, methylphenidate and modafinil, which boost alertness and focus. Anti-dementia drugs improve long-term memory, while beta-blockers reduce stage fright and enhance memory consolidation. Interest is also growing in psychedelic drugs such as LSD and MDMA for their therapeutic potential. Herbal supplements, such as Rhodiola rosea and Ginkgo biloba, help reduce fatigue and enhance memory in the elderly, and amino acid supplements such as D-serine and L-tyrosine show promise in improving cognitive function under acute stress. Modafinil® is widely used to increase wakefulness and alertness, particularly in individuals with sleep disorders.

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48 Andrews, Russel J./Perdikis, Serafeim: Neurotechnology: brain-computer and brain-machine interfaces. 2023. https://www.medlink.com/articles/neurotechnology-brain-computer-and-brain-machine-interfaces, accessed 29 April 2024.

49 Vilela, Marco/Hochberg, Leigh R.: Applications of brain-computer interfaces to the control of robotic and prosthetic arms, 2020, pp. 87-99. https://www.sciencedirect.com/science/article/abs/pii/B9780444639349000081, accessed 28 April 2024.

50 Der Standard: Ist Elon Musks Neuralink-Implantat die Zukunft der Menschheit? 2024. https://www.derstandard.at/story/3000000206178/ist-elon-musks-neuralink-implantat-die-zukunft-der-menschheit, accessed 29 April 2024.

51 UK Ministry of Defence: Development, Concepts and Doctrine Centre (DCDC): Human Augmentation – The Dawn of a New Paradigm. 2021, p. 87f. https://www.gov.uk/government/publications/human-augmentation-the-dawn-of-a-new-paradigm.

These substances primarily impact alertness and memory rather than overall intelligence and can alter brain states with potential trade-offs between cognitive styles. In military settings, they may enhance performance, mitigate fatigue and improve situational awareness, but require careful monitoring for safety and effectiveness.[52]

The legalisation of cannabis in Germany presents specific issues for military personnel. While soldiers face no legal repercussions for recreational cannabis use outside of duty, it remains prohibited in military settings, with penalties for infractions. Some advocate revisiting this zero-tolerance policy, similar to Canada's approach, considering factors such as military readiness, soldiers' health and societal attitudes towards cannabis.[53]

3.2.3 Concentration and vigilance

To enhance concentration and sustain attention, various biochemical and pharmacological methods for performance enhancement are available. Modafinil®, for instance, was previously cited as an example. Additionally, advancements in attention (vigilance) over prolonged periods have been achieved through techniques such as transcranial stimulation.[54]

Peripheral nerve stimulation for cognitive enhancement: non-invasive brain stimulation techniques such as transcranial direct current stimulation (tDCS), which can enhance cognitive functions, similar to the example of tDCS being used for cognitive enhancement in military training scenarios.[55]

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[52] Idem. It is important to note that the transfer of results of studies with sick patients cannot occur without further ado and is scientifically presuppositional. This opens up a field of extensive research.

[53] Bombeke, Yann: Cannabis wird in Deutschland legal – aber auch für Soldaten? 2023. https://www.dbwv.de/aktuelle-themen/blickpunkt/beitrag/cannabis-wird-in-deutschland-legal-aber-auch-fuer-soldaten, accessed 1 May 2024.

[54] Brühl, Annette/d'Angelo, Camilla/Sahakian, Barbara J.: Neuroethical Issues in Cognitive Enhancement: Modafinil as the Example of a Workplace Drug? 2019. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7058249/, accessed 2 May 2024.

[55] Idem.

3.2.4 Memory

Improvement in memory and recall. Improvements in memory have been achieved with transcranial stimulation.[56]

3.2.5 Communication

Interaction with other people - communication as a means[57]

Human interaction with the environment involves three key processes:

- Perception: gathering information through sensory input.
- Cognition: interpreting, processing, storing information and preparing responses.
- Action: responding to the environment through communication, which can be verbal or nonverbal (e.g. facial expressions, gestures, written signs). To prevent misunderstandings in the interpretation of information, knowledge of cultural peculiarities and foreign language skills are advantageous.[58]

Social media has profoundly transformed communication in the past 15 years, influencing the social, economic and political spheres. With over 3.5 billion daily users – representing 45% of the global population –it has become a powerful tool in shaping perceptions and behaviours, making it crucial for considerations in defence, security and safety.[59]

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[56] Phipps, Connor J./Murman, Daniel L./Warren, David E.: Stimulating Memory: Reviewing Interventions Using Repetitive Transcranial Magnetic Stimulation to Enhance or Restore Memory Abilities. 2021. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8533697/#:~:text=Specifically%2C%20transcranial%20magnetic%20stimulation%20(TMS,symptomatic%20treatment%20for%20memory%20loss, accessed 1 May 2024.

[57] Der Standard: VR-Brille soll Sprachenlernen Leichter machen. 2017. https://www.derstandard.at/story/2000054546715/vr-brille-soll-sprachenlernen-leichter-machen, accessed 1 May 2024.

[58] Idem.

[59] NATO: Science and Technology Trends 2023-2043 – Across the Physical, Biological, and Information Domains. 2023, p. 67. https://www.nato.int/nato_static_fl2014/assets/pdf/2023/3/pdf/stt23-vol2.pdf, accessed 28 April 2024.

Silent speech interface (SSI) systems[60]

In aerospace and defence, AR and VR interfaces often face issues with cumbersome input mechanisms. Silent speech interfaces using non-invasive EMG electrodes offer a potential solution for controlling military equipment, such as head-up displays (HUDs) and AR systems. Developing seamless, low-profile input methods is crucial in maintaining discretion and efficiency in military contexts. While current interfaces are proof-of-concept, further research is needed to validate their feasibility and integrate them with devices such as Microsoft HoloLens for practical AR applications.[61]

3.2.6 Strengthening the will and motivation

There are several ways to strengthen motivation and willpower. On one hand, techniques and specific motivation training can be used to enhance mental strength and perseverance. On the other hand, medications, with careful consideration of risk and benefit, can also be supportive in achieving this goal.

Motivation, the drive to achieve goals, is a key focus of smart drugs such as stimulants, which target arousal and the dopaminergic system.[62] Attention, closely linked to motivation, is influenced by the cholinergic system. Besides drugs, software interventions can fine-tune motivation by directing attention and employing conditioning techniques.[63] Managing boredom, attention and drive is crucial across contexts. However, substances used for motivation enhancement can have unintended side effects, prompting the exploration of nanomaterials for precise control. Emotional enhancements such as trust and empathy are vital, requiring breakthroughs in neuropsychology and ethical considerations. Strengthening willpower can prioritise long-term goals, while addressing boredom is essential to enhance motivation.[64]

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60 Flanagan, Riley/Rivas, Tania: Wearable Silent Speech Interface for Augmented Reality Applications. 2020. https://commons.erau.edu/cgi/viewcontent.cgi?article=1550&context=discovery-day, accessed 1 May 2024.

61 Idem.

62 UK Ministry of Defence: Development, Concepts and Doctrine Centre (DCDC): Human Augmentation – The Dawn of a New Paradigm. 2021, p. 89. https://www.gov.uk/government/publications/human-augmentation-the-dawn-of-a-new-paradigm.

63 Idem.

64 Ibid., p. 90.

3.3 Social enhancement

Social enhancements emphasise improving communication, leadership and teamwork abilities. Training programmes and advanced communication tools are crucial in enhancing these skills.

Social media and networks:[65] aids in intelligence collection, targeting, command and control, defence and psychological warfare, enhancing overall operational effectiveness by leveraging information from social platforms.

- **Increasing complexity in research**: advanced methods for understanding, modelling and simulating social networks are enhancing our grasp of human social behaviour.
- **Predicting emergent properties**: this complexity aids in predicting the emergent properties of social systems, crucial in tackling disinformation and hybrid warfare campaigns.
- **Virtual reality applications**: the use of virtual reality to augment social interactions is growing, with significant implications for both civil and military sectors.
- **Link to human-machine teaming**: developments in social network dynamics and virtual reality are increasingly intersecting with human-machine teaming strategies.[66]

4. Humans in the information environment – Information as the key

Crucial to human enhancement is a holistic perspective; individual optimisations yield little benefit if they cannot be efficiently processed and implemented. Remember: it is all about the systematic applicability of biological-technical solutions to increase military performance and operational capability. This goal constantly raises new questions, the answers to which require information to be processed and decisions to be made. In an environment inundated with stimuli, individuals are only capable of optimised performance *when they can adapt and improve their cognitive abilities and decision-making processes*. Figure 4 illustrates this cycle and its dependencies.

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[65] NATO: Science and Technology Trends 2023-2043 – Across the Physical, Biological, and Information Domains. 2023, p. 66. https://www.nato.int/nato_static_fl2014/assets/pdf/2023/3/pdf/stt23-vol1.pdf.

[66] Idem.

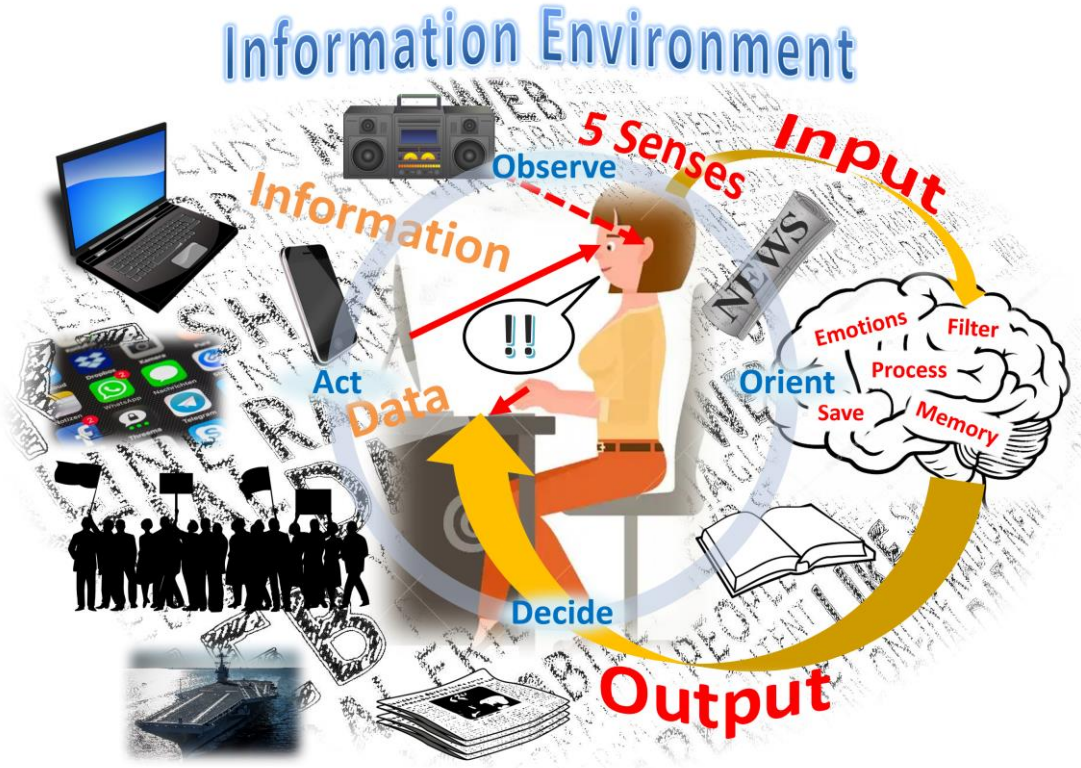

Figure 4: The human in the information environment – The cycle of cognition consists of perceiving information through the senses, further filtering it within the cognitive process, processing it considering emotions and experiences, storing it and then re-entering into interaction with the environment through communication. Information can be diverse, both physical and digital – data becomes information when it is individually of interest. HPO and HPE serve to optimise or improve individual steps within the OODA loop, while considering the overall value. Source: Authors.

The following are some of these dependencies and developmental steps:

Neural interfaces:[67] enable rapid data transfer and control between the brain and devices, improving situational awareness and decision-making.

[67] Idem.

Bioinformatics:[68] utilised for the collection, classification, storage, retrieval and analysis of biological and biochemical data, supporting predictive diagnostics and personalised medicine.

Personalised training and performance metrics:[69] enable tailored training programmes and real-time performance monitoring, optimising individual and team performance.

5. Human augmentation and the OODA loop – Optimising the cognitive edge and fostering continuous improvement

In today's information-saturated environment, quick and effective decision-making is essential. Optimising cognitive processes is crucial in distinguishing useful patterns from noise.[70] This chapter explores how the OODA loop – a cyclical decision-making framework developed by military strategist Colonel John Boyd – enhances cognitive performance in dynamic situations.[71] The OODA loop, comprising Observe, Orient, Decide and Act, provides a robust template for continuous improvement in military contexts and human augmentation.

Why the OODA loop and not another model

The OODA loop's iterative and adaptive approach sets it apart from linear decision models, which often struggle in rapidly changing environments. Its cyclic nature allows for continuous adjustments based on new information, crucial in maintaining initiative and strategic agility. This model aligns well with the need for ongoing learning and optimisation, especially in military applications where rapid decision-making is paramount.[72]

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68 Idem.

69 Idem.

70 Lynn, Spencer K./Barrett, Lisa F.: "Utilizing" signal detection theory. 2014. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4304641/, accessed 26 June 2024.

71 Coram, Robert: Boyd. The Fighter Pilot who changed the Art of War. New York: Hachette Book Group. 2010; Boyd, John. Patterns of Conflict. Defense and the National Interest. Atlanta, accessed in April 2024 and available in PDF format at http://www.d-n-i.net; Boyd, John: Destruction and Creation. U.S. Army Command and General Staff College. 1976; Brown, Ian T.: A New Conception of War: John Boyd, the U.S. Marines, and Maneuver Warfare. Marine Corps University Press. 2018.

72 Wetzel, Tyson: *The New Green Book: The Need for an Anthology of John Boyd's Work,* https://www.colonelboyd.com/understanding-war, accessed 30 June 2024.

5.1 The OODA loop – Enhancing military performance through continuous improvement

The OODA loop transcends immediate decision-making, serving as a framework for continuous improvement at all levels of military operations:

- **Observation:** soldiers and units actively collect performance data through after-action reviews, live-fire exercises, fitness assessments and feedback mechanisms.
- **Orientation:** data is scrutinised to identify individual skill deficiencies, team tactic weaknesses and operational gaps. Understanding underlying causes – whether inadequate training, equipment constraints or communication breakdowns – is critical.
- **Decision:** informed choices lead to tailored improvement initiatives. Individual soldiers may undergo specialised training, teams might adopt new communication protocols and leadership could pivot strategies based on evolving dynamics.
- **Action:** decisions translate into targeted skill-building exercises, revised tactics and enhanced communication protocols. Leadership implements changes in deployment strategies, technology applications and training regimens.

Benefits of the OODA loop for military improvement:

- *Rapid learning*: continuous feedback fosters rapid adaptation from diverse experiences.
- *Mission optimisation*: constant evaluation improves operational strategies and tactics.
- *Maintaining the competitive edge*: the cycle ensures adaptability in the face of evolving threats and technologies.

Examples of the OODA loop in military applications:

- *A Special Forces unit*: observes enemy tactics, identifies a defensive vulnerability, decides on a new infiltration approach and executes a surprise attack.

- *A fighter pilot*: analyses after-action reports, identifies areas for improvement, decides on specific training exercises and practises manoeuvres.
- *Military leadership*: reviews intelligence reports, identifies weaknesses, decides on new hardware acquisitions or training programmes and implements changes.

5.2 The OODA loop and the cognitive dimension

The OODA loop offers a powerful framework for optimising information processing within the human brain, a crucial enhancement avenue for military human augmentation. This section focuses on the core information processing capabilities of the human mind and how augmentation can enhance them.

Elevating cognitive performance –
The human element in military operations

In military operations, cognitive processes are crucial for soldiers navigating complex and high-pressure environments.[73] Focusing on training to refine perception, thought processes and actions is essential in enhancing cognitive performance. This approach complements technological advancements by focusing on the human element as a primary enhancement avenue.

Tapping into the powerhouse with the OODA loop to optimise information processing as an enhancement aspect in human augmentation[74]

The OODA loop highlights the stages of information processing in military contexts: observation, orientation, decision and action. Integrating augmen-

[73] Schulyok, Bernhard/Grangl, Lukas/Gruber, Markus: The Importance Of Cognitive Superiority – A Primer On The Functional Trinity Of The Information Environment. In: *The Defence Horizon Journa*l. 2023. https://doi.org/10.5281/zenodo.8405013, accessed 25 May 2024.

[74] Overview compiled and synthesised from contributions and inspirations from the following authors and their respective works: Department of the Navy. 2018; Warfighting, MCDP-1; Department of the Navy United States Marine Corps (USMC). Washington; Brown, Ian T.: A New Conception of War: John Boyd, the U.S. Marines, and Maneuver Warfare. Marine Corps University Press. 2018; Coram, Robert: Boyd. The Fighter Pilot who changed the Art of War. Hachette Book Group. New York. 2010; McChrystal, G. S. et al.: Team of Teams. Portfolio Penguin. 2015.

tation technologies within this framework offers potential for optimisation at each stage.

Observe

- Soldiers actively gather and prioritise critical information from their environment. Augmentation can enhance observation through improved data collection and interpretation.
    - **Application example:** wearable sensors and brain-computer interfaces (BCIs) could refine data collection and filter irrelevant sensory inputs, focusing on critical cues and accelerating threat detection.

Orient

- Soldiers interpret and contextualise information to understand the battlefield. Augmentation can expedite this process through real-time analysis and enhanced situational awareness.
    - **Application example:** BCIs could provide real-time data analysis and augmented mental maps, aiding in quicker orientation and better informed decision-making.

Decide

- Rapid and accurate decision-making is crucial under pressure. Cognitive enhancement strategies can improve decision speed and accuracy.
    - **Application example:** Nootropics and targeted brain stimulation could enhance focus, while decision support systems via BCIs offer real-time aids and optimal action suggestions.

Act

- Translating decisions into action efficiently involves coordination and adaptability. Physical training and motor skill development are currently essential, but future technologies may enhance this process.
    - **Application example:** exoskeletons or neural interfaces could improve motor control and reaction times, while BCIs might enable more direct control over weaponry and communication systems.

The OODA loop enhances military information processing by optimising perception, thought processes and action, fostering sharper cognitive abilities and efficient decision-making. Its dual role as both tool and framework supports continuous improvement and adaptation, crucial in enhancing military effectiveness through human augmentation.

6. Outlook

Systematic integration for military enhancement

A holistic approach integrating biological and technical solutions is vital to boost military performance. This involves optimising cognition – sensing, processing and interacting with information – to enhance operational capability.

Technological and cognitive advancements

Neural interfaces and bioinformatics advance situational awareness and personalised medicine. These technologies enable rapid brain-device data transfer, efficient data management and support predictive diagnostics and tailored training for performance optimisation.

Ethical and strategic considerations

Cognitive and technological enhancements raise ethical, social and legal concerns. Using frameworks like the human-as-a-platform model helps ensure responsible development, balancing enhancements with ethical considerations to maintain public trust and gain strategic advantages.

The integration of disruptive technologies with artificial intelligence enables developments that were unthinkable just a decade ago. The following table presents, for example, NATO's assessed necessity of development and identifies areas for focused research (Fig. 5):[75]

[75] NATO: Science and Technology Trends 2023-2043 – Across the Physical, Biological, and Information Domains. 2023, p. 73. https://www.nato.int/nato_static_fl2014/assets/pdf/2023/3/pdf/stt23-vol2.pdf, accessed 28 April 2024.

Survey Results

The following table presents the assessed potential impact, state and rate of development and identifies areas for focused research.

Table C.1: *Biological and Human Enhancement Technologies (BHET) 2023 - 2043.*

EDT	Technology Focus Areas	Impact	TRL	Horizon
BHET	Bio-engineering & Genetics	High	5-6	2030-2035
	Bio-informatics	High	7-8	2025-2030
	Bio-manufacturing	High	3-4	2030-2035
	Bio-sensors & Bio-electronics	High	3-4	2030-2035
	Cognitive Enhancement	Revolutionary	3-4	2035 or (+)
	Human-Machine Symbiosis	Revolutionary	3-4	2035 or (+)
	Physical Enhancement	High	5-6	2030-2035
	Social Enhancement	High	5-6	2030-2035

Figure 5: NATO's assessed necessity of development and identified areas for focused research (*TRL – Technology Readiness Levels, EDT – Emerging and/or Disruptive Technology)*

Civilian and military research efforts, exemplified by DARPA, are increasingly intertwined, highlighting the need for vigilance as humanity transitions towards advanced combat technologies. DARPA's work includes remote-controlled helmets using transcranial ultrasound to enhance attention, manipulate emotions and reduce sensitivity to fear and pain.[76]

Bio and human enhancement technologies (BHETs) expected in the next 20 years will redefine soldiers, sailors and aviators.[77]

DARPA's advancements in bioengineering and genetics aim to revolutionise military operations with novel biotechnologies. Initiatives such as the BRAIN programme focus on neurostimulation and brain-computer interfaces to enhance soldiers' decision-making and cognitive functions, optimis-

[76] Der Standard: G.I.s durch Ultraschall aus dem Helm stimuliert. 2010. https://www.derstandard.at/story/1282979404209/zukunftsaussicht-gis-durch-ultraschall-aus-dem-helm-stimuliert?ref=article, accessed 1 May 2024.

[77] NATO: Science and Technology Trends 2023-2043 – Across the Physical, Biological, and Information Domains. 2023, p. 64. https://www.nato.int/nato_static_fl2014/assets/pdf/2023/3/pdf/stt23-vol1.pdf, accessed 1 May 2024.

ing resilience and effectiveness in combat[78] and shaping the future of warfare in information-rich environments.[79]

In the realm of bio and human enhancement technologies, a plethora of innovative advancements are on the horizon, each poised to revolutionise military capabilities and operations:[80]

- **Super sensing:** enhancing human senses and cognitive abilities through neurotechnology, improving learning speed and reaction times.
- **Body self-repair:** utilising DNA restructuring and synthetic biology for wound healing and tissue regeneration.
- **Bio-databases:** employing living organisms for secure and efficient data storage and processing.
- **Human-machine integration:** augmenting soldiers with exoskeletons or internal enhancements for increased strength, balance and speed.
- **Chemical or biological analysis:** instant substance identification to bolster threat detection and situational awareness.
- **Health monitoring:** continuous tracking of individual health to optimise performance and resilience.
- **Realistic training environments:** using virtual or augmented reality to create immersive, lifelike training scenarios.
- **Psychotic effects:** researching the remote induction of mass hysteria or hallucinations for psychological warfare.
- **Genetic targeting:** designing targeted pathogens or antidotes for strategic defence and offence.
- **Bio-infrastructure:** developing stealth infrastructure with bio-concrete for covert operations in austere environments.
- **Living sensors:** utilising bacteria to detect mines, monitor intrusions and identify early CBRN threats.

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[78] NATO: Science and Technology Trends 2023-2043 – Across the Physical, Biological, and Information Domains. 2023, p. 74. https://www.nato.int/nato_static_fl2014/assets/pdf/2023/3/pdf/stt23-vol2.pdf, accessed 28 April 2024.

[79] Idem.

[80] Idem.

6.1 Takeaways

- **Holistic human enhancement:** combining biological and technical solutions optimises sensing, processing and decision-making to enhance military performance.
- **Advancements in technology and cognition:** neural interfaces and bioinformatics improve situational awareness, decision-making and personalised medicine, supporting predictive diagnostics and tailored training.
- **Ethical and strategic considerations:** developing high performance optimisation (HPO) and human performance enhancement (HPE) technologies requires ethical frameworks, such as the human-as-a-platform model, to align with military goals and maintain public trust.
- **Monitoring and response:** continuous monitoring of HPO and HPE advancements ensures adaptability to technological changes and global challenges.
- **Mission integration:** incorporating HPO and HPE into military strategies boosts teamwork, mission success and overall operational effectiveness.

6.2 To-dos

- **Develop integrated solutions:** implement biological and technical innovations to optimise cognitive processes and enhance military performance.
- **Invest in key technologies:** focus on neural interfaces, bioinformatics and related technologies to improve situational awareness, decision-making and medical support.
- **Establish ethical guidelines:** create clear ethical guidelines for the responsible development and deployment of HPO and HPE technologies, addressing ethical, societal and legal aspects.
- **Maintain vigilance and adaptation:** set up mechanisms for ongoing monitoring and adaptation to swiftly respond to technological advancements and geopolitical changes.

- **Integrate into military strategies:** incorporate HPO and HPE enhancements into training programmes and operational planning to optimise teamwork and mission success.

This article highlights advancements in military HPE, emphasising the importance of discerning technology adoption. Beyond technical feasibility, these enhancements are crucial in improving teamwork and mission success. As fitness levels decline, HPO and HPE offer significant opportunities for individual readiness. The OODA loop remains a key tool for evaluating these enhancements, and continuous monitoring is vital to address global challenges, particularly those from nations with fewer ethical constraints.

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Coffman, Brian A./Clark, Vincent P./Parasuraman, Raja: Battery powered thought: Enhancement of attention, learning, and memory in healthy adults using transcranial direct current stimulation. In: NeuroImage, Volume 85, Part 3, 15 January 2014, pp. 895-908, https://www.sciencedirect.com/science/article/abs/pii/S1053811913008550?via%3Dihub, accessed 12 August 2024.

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