Technical Human Advancement

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Introduction

When challenged with the topic of (technically) enhancing human capabilities, human enhancement in general can be said to essentially be as old as mankind itself. Already the invention of spears dating back to the Palaeolithic Age[1] contributed to having greater success when hunting and therefore improved the chances of survival. A modern, popular variant of this trend can also be found in the continuous success of energy drinks. The desire for performance-enhancing substances is reflected in the expected growth of the energy drinks market, increasing approximately + 25% from 2024 to 2029, which is already worth hundreds of billions of Euros.[2] From a military point of view, this topic is always of interest due to the potentially enhanced combat capabilities and sustainability of soldiers. The most innovative development in this field involves technologies that are used for invasive human enhancement, i.e. implants with the aim to enhance human performance in the future. In accordance with the scope of the project, taking a look into the future at this point in time and attempting to predict potential approaches from current developments is therefore indispensable. Addressing this goal, the article focuses on approaches for human advancement, which ultimately result in invasive technical human advancement. This defines the changes to humans made below the surface of the skin (subcutaneous) which fundamentally enhance their capabilities (cognitive, physical, etc.). It indicates ex-

[1] Thieme, Hartmut: Altpaläolithische Holzgeräte aus Schöningen, Lkr. Helmstedt. (Lower Palaeolithic wooden tools from the Schöningen, Helmstedt district) Germania. Anzeiger der Römisch-Germanischen Kommission des Deutschen Archäologischen Instituts. 77 (Bulletin of the Roman-Germanic Commission of the German Archaeological Institute) (2), pp. 451-487. 1999. doi:10.11588/ger.1999.91650.

[2] Statista Research Department: Umsatz mit Energy Drinks und Sportgetränken weltweit in den Jahren 2018 bis 2024 mit einer Prognose bis 2029 (Energy drink and sports drink sales worldwide from 2018 to 2024 with forecast until 2029). Statista. 2024. https://de.statista.com/statistik/daten/studie/1342142/umfrage/umsatz-mit-energy-drinks-und-sportgetreanken-weltweit/,accessed on 11 Nov 2024.

tensions which are at least temporarily implanted into people (such as pacemakers).

This topic has frequently been discussed internationally over a longer period of time, as shown by various publications from the previous century,[3] to more recent publications.[4]

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[3] See e.g.: Druckman, Daniel/Bjork, Robert A.: In the Mind's Eye - Enhancing Human Performance. (N. R. Council, Publ.) Washington, D.C., USA: The National Academies Press. 1991. doi:10.17226/1580; Druckman, Daniel/Bjork, Robert A.: Learning, Remembering, Believing: Enhancing Human Performance. (N. R. Council, Publ.) Washington, D.C., USA: The National Academies Press. 1994. doi:10.17226/2303; Druckman, Daniel/ Swets, John A.: Enhancing Human Performance - Issues, Theories, and Techniques. (N. R. Council, Publ.) Washington, D.C., USA: The National Academies Press. 1988. doi:10.17226/1025. Harris, Monica J., & Rosenthal, Robert: Enhancing Human Performance: Background Papers, Issues of Theory and Methodology. (N. R. Council, Publ.) Washington, D.C., USA: The National Academies Press. 1988. doi:10.17226/779.

[4] See e.g.: Blumenthal, Marjory S./Hottes, Alison K./ Foran, Christy/ Lee, Mary: Technological Approaches to Human Performance Enhancement. Rand Corporation. Santa Monica, CA: Rand Corporation. 2021. https://www.rand.org/pubs/research_reports/RRA1482-2.html, accessed on 30 May 2024; Committee on Assessing Foreign Technology Development in Human Performance Modification: Human Performance Modification: Review of Worldwide Research with a View to the Future. (N. R. Council, Publ.) Washington, D.C., USA: The National Academies Press. 2012. doi:10.17226/13480. Committee on Creating a Framework for Emerging Science, Technology, and Innovation in Health and Medicine: Toward Equitable Innovation in Health and Medicine: A Framework. (N. A. Medicine, Publ.) Washington, D.C., USA: The National Academies Press. 2023. doi:10.17226/27184; Committee on Human-System Integration Research Topics for the 711th Human Performance Wing of the Air Force Research Laboratory: Human-AI Teaming: State-of-the-Art and Research Needs. (N. A. Sciences, Publ.) Washington, D.C., USA: The National Academies Press. 2022. doi:10.17226/26355; Committee on Leveraging the Future Research and Development Ecosystem for the Intelligence Community: Improving the Intelligence Community's. (N. A. Sciences, Publ.) Washington, D.C., USA: The National Academies Press. 2022. doi:10.17226/26355; Committee on Protecting Critical Technologies for National Security in an Era of Openness and Competition: Protecting U.S. Technological Advantage. (N. A. Sciences, Publ.) Washington, D.C., USA: The National Academies Press. 2022. doi:10.17226/26647; Juengst, Eric/ Moseley, Daniel: Human Enhancement. (E. N. Zalta, Publ.). The Stanford Encyclopedia of Philosophy (Summer 2019 Edition). 2019. https://plato.stanford.edu/archives/sum2019/entries/enhancement/, accessed on 14 April 2024.

This article primarily attempts to find a common basis which characterises these developments in order to draw up an example of what the future may look like. Following this introduction, the article is divided into the following sections:

Firstly, the article focuses on covering the possible scope of challenges in human enhancement, then the current variants that are found in medical technology and derives a generally applicable three-phase model from this, which is supposed to form the basis for extrapolating future developments based on the current state of development. The prerequisites which have been established in the meantime for making these new developments possible are also examined.

Following this theoretical illustration, selected examples are used to illustrate what the civil and military situations look like according to the documentation which is publicly available. Building on this, a thought experiment sets out a future scenario, before finishing with a brief explanation of the legal framework conditions for the subject matter and an illustration of selected physiological limits.

This article attempts to clarify the subject matter from a technical perspective. Overlaps with medicine in the medical/technical sector are unavoidable. Due to the wide-range and difficult-to-predict subject area within such a joint publication, statements in other contributions may also appear contradictory and therefore represent a large variety of potential future scenarios.

Distinguishing between scenarios

As well as the generally defined central working hypothesis (trend scenario), at least two borderline scenarios are also considered, since these can have a considerable impact on the meaning of the topic. Based on the scenario technique,[5] a "best case" and a "worst case" regarding human enhancement are derived, which represent the most likely limits of the current topic.

[5] Amongst other things, see Wilms, Falko E. P. (ed.): Szenariotechnik (Scenario technology): Vom Umgang mit der Zukunft (Dealing with the future) (1st ed.). Haupt Verlag. 2006.

Best Case

In the best-case scenario, there is a worldwide ban on human enhancement in the military environment comparable to the initiative which was co-initiated by Austria for achieving a worldwide ban on (fully) lethal autonomous weapons systems (amongst other things, see the "Vienna Conference on Autonomous Weapons Systems" of 29 April 2024).[6] This includes a strict regulation and monitoring of such technologies in order to prevent the uncontrolled spread and illegal use of human enhancement. The permitted use of comparable human enhancement technologies is restricted to military or civil persons with physical or cognitive impairments with the aim of compensating permanent effects, given that these impairments are either inbred or suffered during life. The use of these technologies for relief, healing or bionic reconstruction does not necessarily mean that the affected persons must not be involved in military operations: However, it must be reliably assured at the technical level that the existing artificially technical functionality is limited to the generally expected or previous existing human capability of the corresponding body part or function, and cannot be extended to a human-unlike level, not even temporarily. The primary task of the international community is the technical and legal safeguarding of the related technologies as well as establishing a full control for access to them, but no new military capabilities are achieved.

Worst Case

In a worst-case scenario there are no regulations regarding human enhancement. The technology would be freely available also to extremist or terrorist organisations due to missing or at least ineffective control mechanisms. Those organisations would exploit it using fanatical ideologies such as "God's chosen one(s)" and use it to promote seemingly necessary permanent changes in their followers leading to a spread of human enhancement among those irregular fighters. The primary intention is to maximise the persever-

[6] Federal Ministry for European and International Affairs Department for Disarmament, Arms Control and Non-Proliferation: Humanity at the Crossroads: Autonomous Weapons Systems and the Challenge of Regulation, 2024. https://www.bmeia.gv.at/fileadmin/user_upload/Zentrale/Aussenpolitik/Abruestung/AWS_2024/2024_09_16_AWS_Broschuere.pdf.

ance of fighters in the most harmful way by (almost) fully eliminating sensitivity to pain, fatigue, basic needs such as hunger or thirst or other perceptions which may impair performance. Hormone production is raised to a level that represents the highest level of performance from the person in question, comparable to doping. In case of action, executive and military branches do not have any information about any enhancements applied to adversary forces, meaning that the worst-case scenario must always be assumed. The use of "man-stopping", non-lethal weapons is essentially ineffective, and the only remaining possibility of sustainably neutralising a threat is the targeted killing of such a manipulated opponent. This scenario is exceptionally threatening the internal security of a country, because the current executive forces, including the special forces, are not sufficiently prepared for. The range of capability innovations or enhancements must be regarded as unlimited. In Austria, it is the Federal Armed Forces who might then face such issues as assistants to the police and being sufficiently armed and equipped for.

On the other hand, the possibility that human enhancement technologies could be used for psychological support should not be ignored, particularly for soldiers during combat operations, as well as their potential to provide soldiers with technical protection from the effects of post-traumatic stress disorder.

The way to Human Enhancement

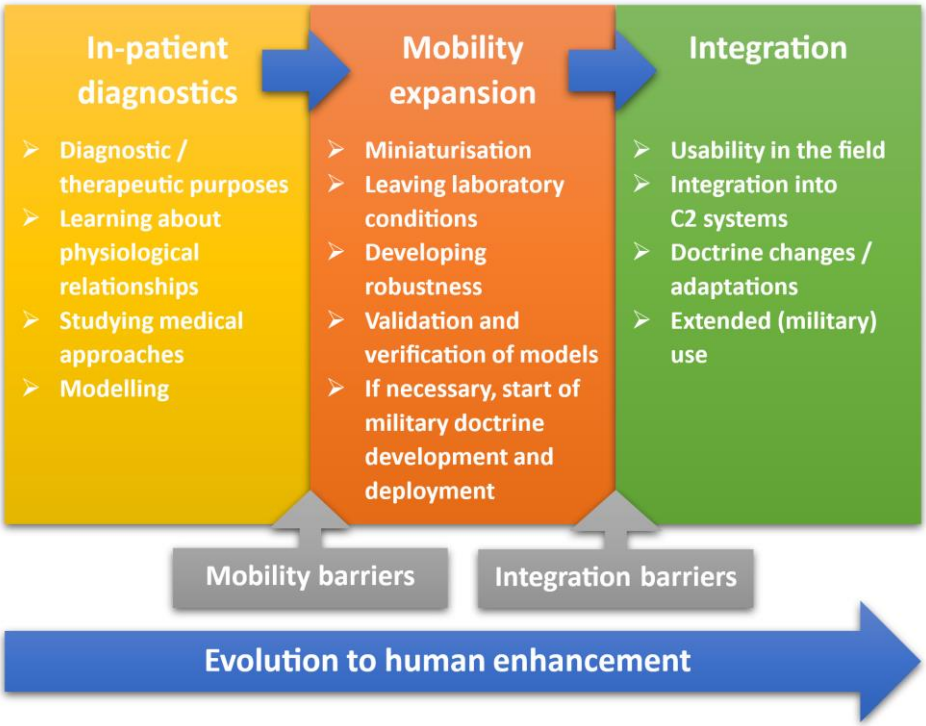
Human enhancement is generally the result of decades or even centuries of ongoing research and development. For this reason, developments such as this are not necessarily surprising, but are a result of the former development of existing medical knowledge and procedures.

Three fundamental, current variants have been studied to analyse similarities on the way to human enhancement:

- The pacemaker and its precursors
- The Brain-Computer-Interface and the way it emerged
- Current options provided by bionic prostheses and precursors

An underlying, general pattern is recognisable in this case. Existing technologies for human enhancement have been around for decades or even hundreds of years. This generally begins with initially unresolved diagnostic or subsequent therapeutic necessities that are addressed by technological innovations and are rounded off by making these suitable for personal use. In general, this occurs as follows:

Figure 1: Three-stage phase model of human enhancement



Source: Author

In the case of the pacemaker, the path from diagnosing the condition to the use of medication (Digitalis) can be traced back to the 18th century, and Wayne[7] even refers to comparable attempts from the Roman era. At the mo-

[7] Wayne, Thomas F.: Clinical Use of Digitalis: A State of the Art Review. American Journal on Cardiovascular Drugs: Drugs, Devices and other Inventions, 18(6), pp. 427-440. 2018. doi:10.1007/s40256-018-0292-1.

ment, potential uses include state-of-the-art mobile diagnostic devices and smart watches, which are now sufficiently accurate.[8] Mobile and generally available monitoring of heart activity is therefore a product which arose after a long research period and is still undergoing development.[9]

Comparable processes can also be seen regarding prosthetics and bionic implants. After sufficient studies of the human anatomy resulted in a better understanding, the first prosthetics were used back in the days of Ancient Egypt, to counteract the loss of a toe, for instance.[10] Looking beyond the aesthetics, prosthetics were later used as substitutes for limbs, not just for injuries caused by war, but also as a result of widespread malnutrition.[11] In the meantime, this has developed into a technology that is thoroughly competitive in certain applications, such as Oscar Pistorius and the prosthetic limbs made from carbon. Furthermore, Lindsay Vonn, an exceptionally successful skier, is returning to the World Cup with an artificial knee.[12] However, apart from this there have been new achievements such as a bionic eye which

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[8] Veltmann, Christian: Deutsche Herzstiftung (German Heart Foundation). Mit der Smartwatch Vorhofflimmern erkennen (Detecting atrial fibrillation with a smart watch). 2022. https://herzstiftung.de/infos-zu-herzerkrankungen/herzrhythmusstoerungen/vorhofflimmern/vorhofflimmern-diagnose-smartwatch#welche-smartwatch.

[9] Lemke, Bernd: Geschichte der Herzschrittmacher-Therapie in Deutschland (History of pacemaker therapy in Germany). Herzschrittmachertherapie + Elektrophysiologie (Pacemaker therapy and electro-physiology) (Special Edition 1/2024), pp. 18-54. 2024. doi:10.1007/s00399-024-01010-4.

[10] Dönges, Jan: Eine 3000 Jahre alte Zehenprothese (A 3000 year old toe prosthesis). Spektrum der Wissenschaft (Scientific Spectrum). 2017. https://www.spektrum.de/news/altes-aegypten-eine-3000-jahre-alte-zehenprothese/1465821, accessed on 24 Nov 2024.

[11] Schatz, Iris: Objekte der Nächstenliebe (Objects of Brotherly Love). Deutsches Ärzteblatt (German Medical Papers), 2007, p. 360. https://www.aerzteblatt.de/archiv/54408/Kulturgeschichte-der-Prothesen-Objekte-der-Naechstenliebe.

[12] Welt: Ski Alpin: Comeback Von Lindsey Vonn Mit Künstlichem Knie. DIE WELT, November 19, 2024. https://www.welt.de/sport/wintersport/article254519720/Ski-alpin-Comeback-von-Lindsey-Vonn-mit-kuenstlichem-Knie.html.

has been used in people for the first time,[13] or miniature hearing aids which have been produced using 3D printing.[14]

The development leading to the connections between brain and computer that is currently known as the **Brain-Computer-Interface** is particularly interesting. Most widely discussed, the company Neuralink has invested a lot of effort to bring this topic also to a significant public awareness. This development arises from a long history of Electroencephalography (EEG) development, which made it possible to obtain sufficient knowledge about the human brain.[15] Additionally, knowledge of the human brain also branched to the mathematical / informatics-related research field of neural networks for an artificial representation of the human brain for providing the technological foundation of artificial intelligence, particularly reinforcement learning as one form of enhancement. This reinforcement learning technology[16] inevitably enables these kinds of **Brain-Computer-Interfaces** as bionic implants can adapt to the individual unique behaviour of the connected body part over time, and recognise thought and pulse patterns accordingly. This enables the implants to integrate themselves into the body's internal environment.

Phase 1: Medical/technological applications

Medical technology development is the starting basis. However, it primarily focusses on healing ailments, and therefore on compensating physical defi-

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[13] NIHR Moorfields Biomedical Research Centre: Moorfields patient receives bionic chip implant in blind eye. 2022. https://moorfieldsbrc.nihr.ac.uk/nihr-moorfields-biomedical-research-centre-receives-20-million-for-another-five-years-of-vision-research-innovation/, accessed on 30 May 2024.

[14] 3DSourced: How 3D Printed Hearing Aids Silently Took Over The World, accessed on 30 May 2024 from 3DSourced: The World's Most Informative 3D Printing Source. 2023. https://www.3dsourced.com/editors-picks/custom-hearing-aids-3d-printed/.

[15] Wilcken, Sandra: Die Geschichte des EEG in der Hirnforschung – von den Anfängen bis zum goldenen Zeitalter (The History of EEG in Brain Research – from the Beginnings to the Golden Age), accessed from Deutsche Gesellschaft für Klinische Neurophysiologie und Funktionelle Bildgebung (DGKN) e.V. 2024. https://dgkn.de/dgkn/presse/pressemitteilungen/478-die-geschichte-des-eeg-in-der-hirnforschung-von-den-anfaengen-bis-zum-goldenen-zeitalter.

[16] Ris-Ala, Rafael: Fundamentals of Reinforcement Learning. Springer Nature Switzerland. 2023.

cits that have either been suffered or inbred using medical/technical diagnosis, chemistry, physics and other relevant scientific fields. From a representative pool of data, medical statistics obtain information regarding normal values, acceptable deviations or those which require treatment, or deviations which are beyond the acceptable parameter ranges.

Figure 2: Example of classifying blood pressure[17]

	Systolic (mmHg)	Diastolic (mmHg)
Optimal	**< 120**	**< 80**
Normal	**120 - 129**	**80 - 84**
Prehypertension	**130 - 139**	**85 - 89**
Grade 1 Hypertension	**140 - 159**	**90 - 99**
Grade 2 Hypertension	**160 - 179**	**100 - 109**
Grade 3 Hypertension	**> 180**	**> 110**

As medicine endeavours to return people suffering from ailments (=people with diagnostic values which lie outside a generally specified normal state determined in relation to the basic population) to this representative domain, it can basically not be assumed that target values (a.k.a. benchmarks) can be obtained or determined for the maximum performance capability which can be achieved. Note: This approach is also rigorously being applied in the area of doping, where performance-enhancing substances are also forbidden in the interests of maintaining fair competition.

Nevertheless, this first phase is essential in order to obtain sufficient information about the anatomy and physiology of the part of the human body investigated. It creates the basis for the set of treatment approaches possible, as well as the limits of impact on the human body. These limits must not be regarded as absolute, as shown by recent immunisation and healing methods

[17] Guyton, Arthur C./Hall, John E.: Guyton and Hall textbook of medical physiology. USA: (12th ed.). USA: Saunders. 2011.

made possible by genetic developments (e.g.: CAR-T cell therapy for combating leukaemia or mRNA-based vaccinations),[18] but move along with the ever-increasing knowledge of the human body.

This gathering of information represents the basis for producing models which act as a risk-free development basis for new applications. An example of this, which ought to be mentioned, are the cardiovascular research from the Austrian Institute of Technology[19]or the publication on the possibility of using artificial intelligence to create new approaches for medications based on existing knowledge.[20] This model development part leads to a situation in which at first new and previously unresearched questions for a more comprehensive study emerge during model development and also during the course of the validation and verification of the models, whilst the validated and verified model subsequently becomes available for experiments which could not be carried out on a living object for ethical or risk-related reasons, or could only be carried out at great expense.

The models do not always have to be in direct relation to the medical technology but can also be used in other scientific areas. The winners of the 2024 Nobel Prize for Physics Geoffrey Everest Hinton and John Hopfield used the functionality of the human brain that was known at the time for the purpose of machine learning. Human learning was well imitated even at the beginning of the 1990s, with the widespread approach of the Backpropagation of Error in supervised learning. This approach determines the outcome for a specified task and in the event of an error, the individual weightings of the network are appropriately adapted / modified by means of back-calculations. This barely differs from writing a text and correcting any spelling mistakes, which is how a schoolchild learns how to improve its spelling.

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[18] A discussion about immunisation against COVID-19 is not going to take place at this point, merely a reference to the technological basis of such vaccinations.

[19] AIT Austrian Institute of Technology GmbH: Cardiovascular Diagnostics. https://www.ait.ac.at/themen/cardiovascular-diagnostics, accessed on 10 Oct 2024.

[20] Gupta, Rohan/ Srivastava, Devesh/ Sahu, Mehar/ Tiwari, Swati/ Ambasta, Rashmi K./ Kumar, Pravir: Artificial intelligence to deep learning: machine intelligence approach for drug discovery. Molecular Diversity (25), pp. 1315-1360. 2021. doi:10.1007/s11030-021-10217-3.

Furthermore, the "genetic algorithms"[21] behind Darwin's theory of evolution have been used to develop a well-known and frequently used procedure for optimising large-scale (mathematical) (called NP-hard) problems. The basics of the "survival of the fittest" are also established with a wide range of features within fauna.

Phase 2: Extending mobility

The acquired results and physical applications are generally static in phase 1 within a controlled environment (laboratory, hospital), and may therefore not be sufficiently representative. Furthermore, fundamental technological developments are not a basis for statements regarding stressful situations which arise outside standardised medical test procedures (e.g. stress ECG).

To propagate medical knowledge and create a more comprehensive knowledge, aside of lowering side-effects medical technology also seeks to apply diagnostic approaches and procedures via miniaturisation and energy autonomy of diagnostic equipment for prolonged periods within the patient's normal environment in order to obtain more realistic diagnostic data and information which is more representative in real life. This requires thresholds to be bridged which can be shown as follows, for example:

- Impact on the typical course of life (weight, size, additional tasks, visibility and societal reservations)
- Safety of the procedure
- Restrictions to quality of life
- Expense for energy supply

In a military environment, the load from existing equipment can also be added to this.[22] The additional load must also be noted in contrast to the benefit, particularly for soldiers. A wide range of publications on the subject

[21] Goldberg David E.: Genetic Algorithms. Addison-Wesley. 1989.

[22] Townsend, Stephen J.: THE FACTORS OF SOLDIER'S LOAD. Master's Thesis, U.S. Army Command and General Staff College, Fort Leavenworth. 1994. https://apps.dtic.mil/sti/tr/pdf/ADA284389.pdf.

of the load on soldiers due to additional equipment in general can be found in the scientific literature.[23]

In particular, these loads include:

- Energy supply in the field
- Reliability and security of data transmission
- Security regarding electronic intelligence (ELINT)
- Weight and size
- Sensory overload during deployment

The easier it is for a technology to be integrated into an existing system (already temporarily invasive in some cases, not yet invasive in others), the more likely it is to be accepted, regarded as a natural part of daily life and will therefore provide more comprehensive results. This also applies to technology which already provides assistance in a non-invasive form.

ECG is one example of such mobilisation, particularly in diagnosing atrial fibrillation. Starting from classical systems (12-channel ECG), the technology has developed in such a way that current information such as that from smart watches can already regarded as suitable for supporting a diagnosis at least to a limited extent.[24] Alternatively, subcutaneously implemented event recorders are another option.[25]

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[23] Joseph, Aaron/ Wiley, Amy/ Orr, Robin/ Schram, Benjamin/ Dawes, Jay J.: The Impact of Load Carriage on Measures of Power and Agility in Tactical Occupations: A Critical Review. International Journal on Environmental Research and Public Health, 88(15(1)). 2018. doi:10.3390/ijerph15010088; Knapik, Joseph J./ Reynolds, Katy L./Harman, Everett: Soldier Load Carriage: Historical, Physiological, Biomechanical, and Medical Aspects. Military Medicine, 169(1), pp. 45-56. 2004. doi:10.7205/MILMED.169.1.45.

[24] Veltmann, Christian: Deutsche Herzstiftung (German Heart Foundation). Mit der Smartwatch Vorhofflimmern erkennen (Detecting atrial fibrillation with a smart watch). 2022. https://herzstiftung.de/infos-zu-herzerkrankungen/herzrhythmusstoerungen/vorhofflimmern/vorhofflimmern-diagnose-smartwatch#welche-smartwatch.

[25] Klingenheben, Thomas: Deutsche Herzstiftung (German Heart Foundation), accessed on 27 October 2024 from Vorhofflimmern: Diagnose oft nur mit Langzeit-EKG (Atrial fibrillation: diagnosis often only with long-term EEG). 2024. https://herzstiftung.de/infos-zu-herzerkrankungen/herzrhythmusstoerungen/vorhofflimmern/vorhofflimmern-diagnose.

A comparable situation exists with patients with diabetes, where a sensor attached to the skin records glucose values every minute for up to 15 days, before transmitting this data to an app on a mobile phone.

In these cases, the technologies that are used invoke minimal opposition to their use if wearing a smart watch with a much shorter battery life compared to a normal watch is readily accepted by the user, or an implant is hidden beneath the skin.

Examples of relevant military developments in this phase

Example: The approach within the context of the human-brain interface

The development of the human-brain interface follows such a logic. A Joint Helmet Mounted Cueing System (JHMCS) is in use as a preliminary step to a military helmet featuring EEG for several fighter jets (Typhoon, F-35) and also attack helicopters, which allows the pilot to also determine the target for the guided missile mounted on the fighter jet by recording the relevant line of sight.[26] It must be said that unlike the science fiction film "Firefox", the helmet does not have mind control, but does already have complex technologies in place for recording pilot's intentions.[27]

This non-invasive but gesture-controlled interaction with the plane is continued in the F-35 Lightning II. The pilot is therefore even more integrated into the system of the aircraft. Additional helmet weight plays a part as a criterion, for example, particularly with military pilots. Additional loads in strenuous flying manoeuvres must not have a negative impact on the cervical spine. On the other hand, the helmet is connected to the system and there-

[26] Henderson, Freddie P.: Using Helmet Mounted Displays to Designate and Locate Targets in the Urban Environment. Knoxville: University of Tennessee. 2005. https://core.ac.uk/download/pdf/268802086.pdf, accessed on 30 Oct 2024; Pelosi, Michael J.: US Patentnr (US patent number). US7266446B1. 2004. https://worldwide.espacenet.com/patent/search/family/038456985/publication/US7266446B1, accessed on 30 Oct 2024.

[27] Collins Aerospace: F-35 Gen III Helmet Mounted Display System (HMDS). No date. https://www.collinsaerospace.com/what-we-do/industries/military-and-defense/displays-and-controls/airborne/helmet-mounted-displays/f-35-gen-iii-helmet-mounted-display-system.

fore supplied with energy. This also applies to other possible uses of such systems. Comparable equipment for typical infantry soldiers with a helmet, which is provided with power via batteries due to the lack of alternative energy sources, must not lead to increased strain on the soldier due to its weight. These phases of the use of EEG information via external sensors represent an initial basis for the development of military doctrines.

The American military has had similar experiences with the use of Augmented Reality. An article from Kallberg et al. explains the tactical benefits and disadvantages of dependency on technology based on the use of AR/MR with troops. It shows how such an extension can lead to a change in warfare tactics.[28]

Reports from 2023 also revealed that these were not free of technical issues, since Microsoft had to make significant adjustments to its HoloLenses in order to obtain a contract for the delivery of appropriately comprehensive equipment for AR/MR functions to satisfy the needs of the US Army.

In the future, the American army would therefore like to use equipment components enhanced with EEG, particularly a pilot helmet that is equipped with EEG sensors and can influence the aircraft and the weapon controls by analysing the pilot's thought patterns.[29] In addition to the advantage in speed, since the need for manual interaction with the fighter jet is at least partially avoided, this also enables better control of the pilot's state of mind in view of the additional forces that have an impact on the pilot in 5th generation fighter jets. In the future, the system should also be able to automatically land the fighter jet if it recognises that the pilot is unresponsive.

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[28] Kallberg, Jan/ Beitelman, Victor/ Mitsuoka, Victor/ Pittman, Jeremiah/ Boyce, Michael/Arnold, Todd W.: The Tactical Considerations of Augmented and Mixed Reality Implementation. Military Review, pp. 105-113. 2022. https://www.armyupress.army.mil/Journals/Military-Review/English-Edition-Archives/May-June-2022/Kallberg/, accessed on 30 Oct 2024.

[29] Roblin, Sebastién: The Military Is Developing a Helmet That Will Allow Fighter Pilots to Maneuver Their Jets—and Fire Weapons—By Just Thinking About It. Popular Mechanics. 2024. https://www.popularmechanics.com/military/a62719626/darpa-n3-ai-helmet/, accessed on 30 Oct 2024.

There has also been a series of trials and plenty of research into using an exoskeleton as a non-invasive preliminary step towards strengthening the limbs, as described by Gollan, Kaiser or Tucker.[30] Studies regarding the benefits thereof have also been published.[31]

Phase 3: Invasive Human Enhancement

Following the mobilisation of the technology, the third phase is about making it suitable for use by extending the function of existing body parts with technological supplements. This is nothing new, since - to continue with the above-mentioned example of the ECG - life-saving technologies such as pacemakers are already a part of everyday life and society in general. This progress also required decades of development, from the initial application on 8 October 1958 to the modern devices that are used today.

In addition to the mobilisation of the technology, other aspects must be considered that lead to a successful use when advancing towards Invasive Human Enhancement.

1. Electrical energy:
   The human body uses electrical energy to control its muscles. However, production of electrical energy is limited to match these corresponding needs. Typical support in the form of implanted semi-conductors via the body's own production of electricity for autonomous use is currently ruled out. In addition to the initiatives of the chip manufacturers for reducing the electricity usage of the manufactured chips with the aim of running laptops, smartphones, smart watches and other energy-autonomous devices for longer, there is also a

[30] Gollan, Benedikt:. Mit dem Exoskelett wieder gehen lernen (Learning to walk again with an exoskeleton). Research Studios Austria Forschungsgesellschaft. 2021. https://www.researchstudio.at/exoskelett-gehen/; Kaiser, Arvid: "Muscle Suit" verspricht dreifache Körperkraft für 4000 Euro ("Muscle Suit" promises three times the body strength for 4000 Euros). manager Magazin. 2014. https://www.manager-magazin.de/unternehmen/artikel/marktstart-fuer-exoskelett-muscle-suit-in-japan-a-1002743.html, accessed on 30 May 2024; Tucker, Patrick: Russia, US Are In a Military Exoskeleton Race. Defense One. 2018. https://www.defenseone.com/technology/2018/08/russia-us-are-military-exoskeleton-race/150939/.

[31] Slaughter, Paul R./ Rodzak, Katherine M./Fine, Sarah J./ et al.: Evaluation of U.S. Army Soldiers wearing a back exosuit during a field training exercise. Wearable Technologies, 4. 2023. doi:10.1017/wtc.2023.16.

European research project in Germany which focuses on the aspect of energy efficiency.[32]

2. Environmental conditions:
   The implanted environment must correspond to the physical environmental conditions.
3. Adaptability to the individual human psyche:
   The invasive enhancements must be compatible with bodily functions. This is not a trivial matter - even if you consider the complexity of the human brain or the impact of genes on the effectiveness of medication. It is possible to teach the system how to correctly recognise the intentions of the body (training/calibration) with "Reinforcement Learning" methods mentioned above.

The use of invasive technology on the human physiology and psychology must be studied during this phase at the very latest. Particularly the recovery phases of the body parts which are exposed to higher levels of activity due to technological influences should be observed closely to ensure that rest times and partial deactivation of components are adhered to.

Thought experiment:
Extrapolation of opportunities starting from dialysis

Dialysis should be used as a starting point to illustrate the three phases. At the moment, it is used if kidneys are malfunctioning in order to regularly filter toxins which are stored in or produced by the body.

Basically, it would not be unreasonable to regard phase 2 as the time to possibly initiate using such a measure for allowing soldiers to operate in areas with limited biological or chemical contamination for a certain period of time. A personal dosimeter would be used to measure the length of time and the intensity to which the soldier was exposed to the related hazardous substances on site. After a specific period of time or alert by the particular do-

[32] Goll, Niklas.: Fraunhofer IZM. Chips der Zukunft könnten durch Magneteffekt in Elektronen 100-mal weniger Energie verbrauchen (Chips of the future could consume 100 times less energy by means of the magnet effect in electrons). 2023. https://www.izm.fraunhofer.de/de/news_events/tech_news/chips-der-zukunft-koennten-100-mal-weniger-energie-verbrauchen.html, accessed on 27 October 2024.

simeter, the soldier then must return to base in order to filter the absorbed substances out of the body once again using a form of dialysis.

An invasive enhancement (phase 3) involving a personal dialysis equipment in the field for the soldier would be imaginable if the size is properly reduced. This then makes it possible for the soldier or the unit to operate in Anti-access/area denial (A2/AD) theatres which are currently not accessible due to contamination because of continuous filtering and removal of hazardous substances from the body.

Measurability of human enhancement

An approach to measurability of human enhancement is defined mainly based on the concept of statistical significance. Three significance levels and the term "enhancement limit" are defined, starting from a pool of measurement data which represents a representative population.[33]

- A "significant enhancement" is when the person enhanced by such means is among the best 5% in a quantitative evaluation of a civil or military discipline compared to the outcomes of a representative general sample of non-enhanced participants.
- A "highly significant enhancement" is when the person enhanced by such means is among the best 1% in a quantitative evaluation of a civil or military discipline.
- A "highest significant enhancement" is when the person changed by such means is among the best 1‰ in a quantitative evaluation of a civil or military discipline.
- The "enhancement limit" is the maximum possible increase achievable considering the technological opportunities and limitations of the current (computer) technologies or the physical limits of the human body.

[33] Kleppmann, Wilhelm: Versuchsplanung - Produkte und Prozesse optimieren (Design of Experiments - Optimising products and processes) (10th Edition.). Carl Hanser Verlag GmbH & Co. KG. 2020.

No absolute scale is defined as a reference for measurement, but reference is made to the existing metrics or standards. This also correlates with the combat value which shows this relative value.

This theoretical construct shall now be explained by using chess rankings as a practical example: The ELO rating is the measure of the capability of a chess player.[34] The basis of the calculation is the same for all players and was developed in its current approach by the chess player and mathematician Árpád Imre Élő. The FIDE database which is available to the public currently contains 182,467 players with an international ELO rating of greater than zero as of April 2024 and who are also currently regarded as active chess players.

If this database is evaluated in the "Standard Tournament Chess" discipline accordingly, a rating of 2,177 ELO points would be needed for a player to be part of the 95% quantile. This does not correspond to any general FIDE norm yet and covers 9,147 players who are at least at this level. Mental human enhancement when it comes to chess would be seen as a "significant enhancement" if a previously average chess player who is properly equipped with additional artificial calculation power achieves and maintains an ELO ranking of 2,177 points or more as a result.

A highly significant enhancement would be achieved if the 99% quantile of all rankings is maintained, which corresponds to an ELO value of 2,399 points based on the current state of the data: This corresponds to the ranking of a FIDE Master, and is marginally below of the necessary playing strength of an International Master. 1,827 people are playing on this level or even higher.

A high significant enhancement would mean the technology would improve a player to a point where they had an ELO ranking of at least 2,603 points, which would correspond to a Grand Master. 183 chess players are currently in this group, including Austria's best player, Markus Ragger.

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[34] Zermelo, E.: Die Berechnung der Turnier-Ergebnisse als ein Maximumproblem der Wahrscheinlichkeitsrechnung (The calculation of tournament results as a maximization problem of probability calculus). Mathematische Zeitschrift 29, pp. 436–460. 1929. doi: 10.1007/BF01180541.

The enhancement limit would currently be at 3,637 ELO points (see: CCRL index (computerchess.org.uk)) with a variation of ± 12 points (at 95% probability). This is the maximum performance that is currently achieved by the chess program Stockfish 16, being regarded as best-in-class chess program compared to other chess programs which are available on the market and which itself would have the possibility of accessing 4 state-of-the art CPUs in parallel. This value therefore is more than 800 ELO points above the leader in the FIDE rankings, GM Magnus Carlsen, who has an ELO ranking of 2,830 (as of April 2024). This performance limit of the computer program represents an upper limit which cannot be exceeded.

Limits of human enhancement

Management consultant Tom DeMarco also covered this in his books "Slack" and "The Deadline".[35] The statement "People under pressure don't work better; they just work faster" shows the contrast to IT systems. Whereas the latter improves in terms of computing (Moore's Law), the processing speed of the human brain remains consistent and generally cannot be overclocked. The possibility of closely observing the influence of technology on cognitive abilities is therefore possible in this phase.

This is also supported in another area. Starting from stationary EEGs which record the brainwaves on systems installed in the laboratory, Professor Gianluca Borghini and his team at the Sapienza University of Rome started to analyse (military) pilots and drivers, and therefore mobilising the stationary use of EEG.[36] What was examined in this study was the brain's adaptability during the learning phase. Experienced pilots showed less brain activity for the same task in the simulator in comparison to newly trained pilots. The possibility of adapting to new technologies is clearly present, since the human brain is optimised to respond to the amended basic conditions / requirements and therefore works in a more energy-efficient manner.

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[35] DeMarco, Tom: Spielräume - Projektmanagement jenseits von Burn-out, Stress und Effizienzwahn (Playgrounds - Project management beyond burnout, stress and efficiency mania) (1st ed.). Carl Hanser Verlag GmbH & Co. KG. 2001.

[36] Borghini, Gianluca/ Aricò, Pietro/ Di Flumeri, Gianluca/Ronca, Vincenzo/ Giorgi, Andrea/ et. Al.: Air Force Pilot Expertise Assessment during Unusual Attitude. Safety, 8(2). p. 17. 2022. doi: 10.3390/safety8020038.

Even during this phase, limits to human receptiveness and therefore the possibility of integrating technology can be recognised. Sensory overload leads to shorter concentration spans, meaning that users can only concentrate on the content for shorter periods of time.[37] Even with this form of technology mobilisation, this must also be taken into consideration if it is designed for that purpose.

Framework conditions for human enhancement by means of EU legislation

Due to the inevitability of the use of artificial intelligence procedures, the EU AI Act is also primarily important from a technical point of view. Generally speaking, military technologies are exceptions to EU legislation provided they are only used for military purposes.[38] Unlike other countries and continents, aside of ethical considerations, developments must therefore be fully funded by armed forces within the EU, since the legally specified limits mean that they cannot be used for civil developments. As individual countries cannot afford these financial challenges in certain sub-areas, developments in the field of human enhancement within the European context will presumably be driven by joint bodies and initiatives including NATO or EDA.

[37] Aufmerksamkeitsspanne im E-Learning-Zeitalter (Attention span in the e-learning era). Copendia GmbH & Co KG – Logo. 2024. https://copendia.de/2024/04/09/aufmerksamkeitsspanne-im-e-learning-zeitalter/, accessed on 27 October 2024.

[38] European Union: Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 June 2024 laying down harmonised rules on artificial intelligence and amending Regulations. 2024. EUR-Lex - Access to European Union law: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202401689&qid=1733759024686, accessed on 9 December 2024.

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