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Cognitive enhancement – A critical reflection from psychology and neuroscience

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1. Introduction

Becoming smarter, healthier and more beautiful has long been at the heart of humanity.[1] In the 21st century, in particular, the topic of human enhancement has become ubiquitous – partly due to the transhumanist movement.[2] Transhumanism is a rather recent philosophical movement promoting and praising the development of technologies aiming to enhance human psychological and physical capabilities.[3] [4] The transhumanist community is numerically small but very well organised and funded; its activities have been characterised as secular faith and techno-idolatry.[5] [6] The main goal of this movement is a substantial enhancement of human capabilities, such as intelligence, creativity, social competencies, morality/values and character – with the final goal that we become "superhumans" who can find solutions to the world's most pressing problems, like the climate crisis, social inequality and the loss of democratic values.[7] Transhumanists propose that enhancement can be achieved through (neuro)technical or pharmacological methods that should be widely applied to healthy individuals – fundamentally transforming human existence (see working definition).

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1 See Pauen, Michael: Autonomie und Enhancement. In: Viertbauer, Klaus/Kögerler, Reinhart (ed.): Neuroenhancement: die philosophische Debatte. Berlin 2019, pp. 89-114.

2 On the transhumanist movement, see also Tragbar, Lisa/Lagos, Rodrigo: Human enhancement for military purposes: Ethical considerations. In chapter ETHICS in this publication.

3 For an overview, see Ranisch, Robert/Sorgner, Stefan L.: Post- and Transhumanism: An Introduction. Frankfurt am Main 2014.

4 For critical accounts, see Grassie, William/Hansell, Gregory R.: Introduction H±: Transhumanism and Its Critics. In: Hansell, Gregory R./Grassie, William (ed.): Metanexus Institute. Philadelphia 2011.

5 Tirosh-Samuelson, Hava: Transhumanism. In: Zygon, 47/2012, pp. 659-1027.

6 Tirosh-Samuelson, Hava: The Paradoxes of Transhumanism: Technological Spirituality or Techno-Idolatry? In: Theologische Literaturzeitung, 146/2021, pp. 123-146.

7 See Liao, Matthew S./Sandberg, Anders/Roache, Rebecca: Human Engineering and Climate Change. In: Ethics, Policy & Environment, 15/2012, pp. 206-221.

But what does human enhancement actually mean and entail? Human enhancement is a rather broad term, encompassing different forms of enhancement targeting different human characteristics. It includes the enhancement of the human body, cognition, personality or even morality.[8] Importantly, we need to make a careful distinction between enhancement of healthy individuals – as is discussed in this chapter – and compensation for diagnosed diseases or disorders in patients. Both are sometimes referred to by the term "enhancement", but they should not be intermixed, as research findings cannot be transferred from one area (e.g. clinical studies with patients) to another (e.g. healthy samples).[9] Here we refer to the enhancement of healthy humans – as proposed by transhumanism.[10] [11] The overarching goal of human enhancement is to improve people beyond what is "normal" [12] and not to restore cognitive function in the case of disease or disorder. So, taken together, human enhancement as discussed in this chapter refers to the application of different methods (e.g. technologies, pharmaceuticals) to foster human characteristics such as physical and cognitive abilities above and beyond what is considered "normal" (see working definition).

One prominent form of enhancement is the improvement of the human body. For example, new technologies can be used to modify one's body.[13] [14] Through artificial body extensions humans can become cyborgs. By applying nanotechnology, they can change their physiology, and they can change their outer appearance with plastic surgery. Another frequently discussed form of

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[8] For the latter, see Gyngell, Chris/Easteal, Simon: Cognitive Diversity and Moral Enhancement. In: Cambridge Quarterly of Healthcare Ethics, 24/1, 2015, pp. 66-74.

[9] See Grinschgl, Sandra/Ninaus, Manuel/Wood, Guilherme/Neubauer, Aljoscha C.: To enhance or not to enhance: A debate about cognitive enhancement from a psychological and neuroscientific perspective. Unpublished manuscript.

[10] See Birnbacher, Dieter: Neuroenhancement – eine ethische Sicht. In: Viertbauer, Klaus/Kögerler, Reinhart (ed.): Neuroenhancement: die philosophische Debatte. Berlin 2019, pp. 18-42.

[11] See Viertbauer, Klaus/Kögerler, Reinhart (ed.): Neuroenhancement: die philosophische Debatte. Berlin 2019.

[12] Almeida, Mara/Diogo, Rui: Human enhancement. In: Evolution, Medicine, and Public Health, 2019/1, pp. 183-189.

[13] See Kourany, Janet A.: Human Enhancement: Making the debate more productive. In: Erkenntnis, 79, 2014, pp. 981-998.

[14] See Ranisch, Robert/Sorgner, Stefan L.: Post- and Transhumanism: An Introduction. Frankfurt am Main 2014.

enhancement is the improvement of human cognitive abilities such as memory, attention or even intelligence.[15] For this form of enhancement, various methods are discussed, such as the use of smart drugs, brain stimulation or gene editing.[16] From a psychologist's and neuroscientist's point of view, this form of enhancement is highly interesting because it targets their core object of investigation – human cognition. Therefore, this chapter will focus specifically on cognitive enhancement and respective research findings from a psychological and neuroscientific perspective.

Besides the heavy promotion of cognitive enhancement within transhumanism[17], this topic is also at the centre of public and academic debates.[18] One reason for this might be the increasing use of modern technologies to support cognitive performance.[19] For example, cognitive offloading – the externalisation of cognitive processes for modern technologies (e.g. storing important information on one's smartphone) – has been extensively studied and shown to improve cognitive performance.[20] Thus, it could be seen as an indirect, external form of cognitive enhancement (i.e. an improvement in cognition mediated by technology use) that is already present in our daily lives. However, it also comes with the fear that relying on technology too much could make people stupid.[21] As a result, other – more direct, internal – ways of improving cognitive performance might be discussed (i.e. an actual improvement in cognition that is not mediated by technology use). Such cognitive enhancement could also help overcome another recent human fear –

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[15] Dresler, Martin/Sandberg, Anders/Bublitz, Christoph/Ohla, Kathrin/Trenado, Carlos/Mroczko-Wąsowicz, Aleksandra/Kühn, Simone/Repantis, Dimitris: Hacking the Brain: Dimensions of Cognitive Enhancement. In: ACS Chemical Neuroscience, 10/3, 2019, pp. 1137-1148.

[16] Bostrom, Nick/Sandberg, Anders: Cognitive enhancement: methods, ethics, regulatory challenges. In: Science and Engineering Ethics, 15, 2009, pp. 311-341.

[17] Sorgner, Stefan L.: On Transhumanism. University Park 2020.

[18] See Dijkstra, Anne M./Schuijff, Mirjam: Public opinions about human enhancement can enhance the expert-only debate: A review study. In: Public Understanding of Science, 25/5, 2016, pp. 588-602.

[19] See Finley, Jason R./Naaz, Farah/Goh, Francine W.: Memory and Technology: How we use information in the brain and the world. Cham 2018.

[20] Grinschgl, Sandra/Papenmeier, Frank/Meyerhoff, Hauke p.:Consequences of cognitive offloading: Boosting performance but diminishing memory. In: Quarterly Journal of Experimental Psychology, 74/9, 2021, pp. 1477-1496.

[21] Carr, Nicholas: Is Google making us stupid? In: The Atlantic, July/August 2008.

the fear of losing jobs to artificial intelligence (AI) technologies.[22] Because of this fear, cognitive enhancement may become increasingly attractive in order to compete with these new AI technologies. In addition, reports of (cognitive) enhancement already in use are appearing not only on social media[23] but also in socially relevant areas such as the military.[24]

In line with the (supposedly) increasing need for cognitive enhancement, rapid advances in technology and medicine provide new opportunities for enhancement. On the one hand, non-invasive methods such as using technical tools as external help[25] or cognitive training[26], as well as non-invasive brain stimulation (e.g. transcranial electric stimulation), are discussed as cognitive enhancement methods. On the other hand, invasive methods such as smart drugs, gene editing and invasive brain stimulation (e.g. deep brain stimulation) and brain-computer interfaces might be applied with the goal of cognitive enhancement.[27] [28] [29]

As outlined at the beginning of this book, the present publication only focuses on invasive enhancement methods; thus, I will further elaborate on

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[22] For example, see Caminiti, Susan: The More Workers Use AI, the More They Worry About Their Job Security, Survey Finds. CNBC. 19 December 2023. https://www.cnbc.com/2023/12/19/the-more-workers-use-ai-the-more-they-worry-about-their-job-security.html.

[23] For example, see Bryan Johnson's Blueprint protocol.

[24] For cognitive enhancement in the US military, see Brunyé, Tad T./Brou, Randy/Doty, Tracy J./Gregory, Frederick D./Hussey, Erika K./Lieberman, Harris R./Loverro, Kari L./Mezzacappa, Elizabeth p./Neumeier, William H./Patton, Debra J./Soares, Jason W./Thomas, Thaddeus P./Yu, Alfred B.: A Review of US Army Research Contributing to Cognitive Enhancement in Military Contexts. In: Journal of Cognitive Enhancement, 4/4, 2020, pp. 453-468.

[25] See cognitive offloading; Risko, Evan F./Gilbert, Sam J.: Cognitive Offloading. In: Trends in Cognitive Sciences, 20/9, 2016, pp. 676-688.

[26] See famous (and highly criticised) study by Jaeggi, Susanne M./Buschkuehl, Martin/Jonides, John/Perrig, Walter J.: Improving fluid intelligence with training on working memory. In: Proceedings of the National Academy of Sciences, 105, 2008, pp. 6829-6833.

[27] For example, Jaušovec, Norbert/Pahor, Anja: Increasing intelligence. London 2017.

[28] For example, Ter Meulen, Ruud/Mohamed, Ahmed D./Hall, Wayne: Introduction. In: Ter Meulen, Ruud/Mohamed, Ahmed D./Hall, Wayne (ed.): Rethinking Cognitive Enhancement. Oxford 2017, pp. 3-14.

[29] For example, Loh, Janina: Trans- und Posthumanismus. Hamburg 2018.

those to (potentially) enhance human cognition. More specifically, my contribution focuses on cognitive enhancement with pharmacological means (i.e. smart drugs and illicit drugs) and (invasive) brain stimulation techniques as well as brain-computer interfaces.

2. Current state of research with regard to cognitive enhancement methods

One crucial problem with regard to debates about cognitive enhancement is the extensive ignorance of relevant scientific evidence and, thus, an inflated hype surrounding enhancement.[30] From a scientific perspective, cognitive enhancement is far less promising than it is sometimes portrayed in, for instance, transhumanist publications but also in general media reports.[31] Furthermore, the rather strong belief in so-called neuromyths (i.e. false beliefs about the human brain due to misinterpreting neuroscientific findings) shows that the public oftentimes has false views of the possibilities and limitations of neuroscience.[32] To help correct those views, I want to highlight central scientific findings with regard to pharmacological enhancement and (invasive) brain stimulation as well as brain-computer interfaces.

Pharmacological enhancement

The intake of different substances to enhance cognition is not a particularly new or extraordinary form of enhancement. For many centuries, coffee has probably been the most distributed cognitive enhancer that improves individuals' wakefulness.[33] Nicotine can also be considered to enhance certain cognitive functions such as working memory or attention.[34] In addition to natural cognitive enhancers, a range of pharmaceuticals with the (believed)

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[30] See Birnbacher, Dieter: Neuroenhancement – eine ethische Sicht. In: Viertbauer, Klaus/Kögerler, Reinhart (ed.): Neuroenhancement: die philosophische Debatte. Berlin 2019, pp. 18-42.

[31] Partridge, Bradley J./Bell, Stephanie K./Lucke, Jayne C./Yeates, Sally/Hall, Wayne D.: Smart Drugs "As Common As Coffee": Media Hype about Neuroenhancement. In: PLoS ONE, 6/11, 2011, e28416.

[32] For example, Grabner, Roland H.: Neuromythen: Fehlvorstellungen über das lernende Gehirn. 2017.

[33] See Jaušovec, Norbert/Pahor, Anja: Increasing intelligence. London 2017.

[34] See Jaušovec, Norbert/Pahor, Anja: Increasing intelligence. London 2017.

potential of cognitive enhancement have been developed.[35] [36] [37] Commonly known as "smart drugs", these substances are often utilised to improve concentration, attention, memory and other cognitive abilities.[38] However, most of these drugs were designed to treat medical conditions. Methylphenidate (e.g. Ritalin), for example, is typically prescribed for ADHD (Attention Deficit Hyperactivity Disorder). It is often misused by students to enhance focus, boost energy levels and improve concentration.[39] [40] Mixed amphetamine salts, such as Adderall, are also taken for cognitive enhancement to enhance mood, physical endurance and concentration.[41] Additionally, modafinil (e.g. Provigil), a medication for narcolepsy, has found off-label use for non-medical purposes to promote wakefulness.[42] [43] Moreover, some illicit substances are used for cognitive enhancement. Taking small amounts of LSD (Lysergsäurediethylamid - lysergic acid diethylamide) or other psychedelics is

[35] De Jongh, Reinoud: Overclocking the brain? The potential and limitations of cognition-enhancing drugs. In: Ter Meulen, Ruud/Mohamed, Ahmed D./Hall, Wayne (ed.): Rethinking Cognitive Enhancement. Oxford 2017, pp. 37-56.

[36] Maher, Brendan: Poll results: Look who's doping. In: Nature. 452/7188, 2008, pp. 674-675.

[37] Schleim, Stephan/Quednow, Boris B.: How Realistic Are the Scientific Assumptions of the Neuroenhancement Debate? Assessing the Pharmacological Optimism and Neuroenhancement Prevalence Hypotheses. In: Frontiers in Pharmacology, 9, 2018, p. 3.

[38] Smith, Elizabeth M./Farah, Martha J.: Are prescription stimulants "smart pills"? The epidemiology and cognitive neuroscience of prescription stimulant use by normal healthy individuals. In: Psychological Bulletin, 137/5, 2011, pp. 717-741.

[39] See McCabe, Sean E./Knight, John R./Teter, Christian J./Wechsler, Henry: Non-medical use of prescription stimulants among US college students: Prevalence and correlates from a national survey. In: Addiction, 100/1, 2005, pp. 96-106.

[40] See Smith, Elizabeth M./Farah, Martha J.: Are prescription stimulants "smart pills"? The epidemiology and cognitive neuroscience of prescription stimulant use by normal healthy individuals. In: Psychological Bulletin, 137/5, 2011, pp. 717-741.

[41] Smith, Elizabeth M./Farah, Martha J.: Are prescription stimulants "smart pills"? The epidemiology and cognitive neuroscience of prescription stimulant use by normal healthy individuals. In: Psychological Bulletin, 137/5, 2011, pp. 717-741.

[42] Jaušovec, Norbert/Pahor, Anja: Increasing intelligence. London 2017.

[43] See Smith, Elizabeth M./Farah, Martha J.: Are prescription stimulants "smart pills"? The epidemiology and cognitive neuroscience of prescription stimulant use by normal healthy individuals. In: Psychological Bulletin, 137/5, 2011, pp. 717-741.

believed to enhance creativity, mood and working memory without triggering a full psychedelic effect.[44] [45]

Transhumanism advocate Ray Kurzweil states that he is altering his body by taking about 250 pills daily and getting multiple infusions weekly to extend his life.[46] Among the general population, the vast distribution of different drugs for cognitive enhancement was shown by a large survey by the publisher Nature. One in five participants – who were mostly from the United States – indicated to have experience with pharmacological enhancers, with methylphenidate being the most favoured.[47] A few years later, Smith and Farah (2011) [48] conducted a review: across different studies from the US and Canada, between 2.30% and 55.00% of the surveyed student samples indicated to have taken prescribed drugs for non-medical purposes.[49] Testing a German sample, Bagusat et al. (2018) showed a life-time prevalence (i.e. applying pharmaceutical enhancement at least once) for cognitive and/or mood enhancement of 38.80%.[50] For an Austrian university student sample, the prevalence was considerably smaller (11.90%).[51] Moreover, a large prev-

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[44] Ona, Genís/Bouso, José C.: Potential safety, benefits, and influence of the placebo effect in microdosing psychedelic drugs: A systematic review. In: Neuroscience & Biobehavioral Reviews, 119, 2020, pp. 194-203.

[45] Pustovrh, Tony/Mali, Franc/Arnaldi, Simone: Are Better Workers Also Better Humans? On Pharmacological Cognitive Enhancement in the Workplace and Conflicting Societal Domains. In: NanoEthics, 12/3, 2018, pp. 301-313.

[46] Kurzweil, Ray: The Singularity Is Near: When Humans Transcend Biology. New York 2005.

[47] Maher, Brendan: Poll results: Look who's doping. In: Nature, 452/7188, 2008, pp. 674-675.

[48] Smith, Elizabeth M./Farah, Martha J.: Are prescription stimulants "smart pills"? The epidemiology and cognitive neuroscience of prescription stimulant use by normal healthy individuals. In: Psychological Bulletin, 137/5, 2011, pp. 717-741.

[49] Smith, Elizabeth M./Farah, Martha J.: Are prescription stimulants "smart pills"? The epidemiology and cognitive neuroscience of prescription stimulant use by normal healthy individuals. In: Psychological Bulletin, 137/5, 2011, pp. 717-741.

[50] Bagusat, Christiana/Kunzler, Angela/Schlecht, Jennifer/Franke, Andreas G./Chmitorz, Andrea/Lieb, Klaus: Pharmacological neuroenhancement and the ability to recover from stress – a representative cross-sectional survey among the German population. In: Substance Abuse Treatment, Prevention, and Policy, 13/1, 2018, p. 37.

[51] Dietz, Pavel/Iberl, Benedikt/Schuett, Emanuel/Van Poppel, Mireille/Ulrich, Rolf/Sattler, Matteo C.: Prevalence Estimates for Pharmacological Neuroenhancement in Austrian University Students: Its Relation to Health-Related Risk Attitude and the Framing Effect of Caffeine Tablets. In: Frontiers in Pharmacology, 9, 2018, p. 494.

alence survey (N = 2,347) on microdosing – the intake of sub-hallucinogenic doses of psychedelic drugs to improve cognitive functions (among others) – showed that 59% of respondents are familiar with it and 17% have actually microdosed.[52] Although there is great variety across prevalence studies on pharmacological enhancement[53], they illustrate a rather broad distribution of smart drugs. It should be noted, however, that those studies predominantly included student populations only. Nevertheless, it is likely that pharmacological enhancement is also used to function at a high level in competitive work environments.[54]

Although the Nature prevalence survey[55] and the review by Smith and Farah (2011)[56] are more than 10 years old, I believe that the prevalence of pharmacological enhancement might be as high or even higher today. This assumption is supported by an increase in scientific publications related to pharmacological enhancement in the past two decades.[57] Furthermore, as the pressure for extraordinary performance is increasing in society[58] and the possi-

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[52] Cameron, Lindsay P./Nazarian, Angela/Olson, David E.: Psychedelic Microdosing: Prevalence and Subjective Effects. In: Journal of Psychoactive Drugs, 52/2, 2020, pp. 113-122.

[53] See Schleim, Stephan/Quednow, Boris B.: How Realistic Are the Scientific Assumptions of the Neuroenhancement Debate? Assessing the Pharmacological Optimism and Neuroenhancement Prevalence Hypotheses. In: Frontiers in Pharmacology, 9, 2018, p. 3.

[54] Pustovrh, Tony/Mali, Franc/Arnaldi, Simone: Are Better Workers Also Better Humans? On Pharmacological Cognitive Enhancement in the Workplace and Conflicting Societal Domains. In: NanoEthics, 12/3, 2018, pp. 301-313.

[55] Maher, Brendan: Poll results: Look who's doping. In: Nature, 452/7188, 2008, pp. 674-675.

[56] Smith, Elizabeth M./Farah, Martha J.: Are prescription stimulants "smart pills"? The epidemiology and cognitive neuroscience of prescription stimulant use by normal healthy individuals. In: Psychological Bulletin, 137/5, 2011, pp. 717-741.

[57] Daubner, Johanna/Muhammad Imran Arshaad/Christina Henseler/Jürgen Hescheler/Dan Ehninger/Karl Broich/Oliver Rawashdeh/Anna Papazoglou/Marco Weiergräber: Pharmacological Neuroenhancement: Current Aspects of Categorization, Epidemiology, Pharmacology, Drug Development, Ethics, and Future Perspectives. Edited by Stuart C. Mangel. In: Neural Plasticity 2021: 1-27.

[58] See Pustovrh, Tony/Mali, Franc/Arnaldi, Simone: Are Better Workers Also Better Humans? On Pharmacological Cognitive Enhancement in the Workplace and Conflicting Societal Domains. In: NanoEthics, 12/3, 2018, pp. 301-313.

bilities to obtain pharmaceuticals (e.g. via the internet) are growing, they may now be even more widely distributed.

Brain stimulation and brain-computer interfaces

Generally, one can differentiate between invasive and non-invasive brain stimulation techniques. Non-invasive techniques include transcranial direct and altering current stimulations (tDCS and tACS) as well as transcranial magnetic stimulation (TMS)[59]. The goal of those methods is to stimulate certain cortical regions and activate neurons therein. Non-invasive brain stimulation has been used rather often to (supposedly) improve, for instance, executive functions, language, memory and visuospatial processing.[60] [61] Even the US military tested transcranial electric stimulation to enhance performance in soldiers.[62]

Invasive brain stimulation techniques such as deep brain stimulation require more severe procedures for enhancement: for those methods, individuals need to undergo surgery to receive a brain implant which can then be used for invasive brain stimulation.[63] Similarly, for invasive brain-computer interfaces (BCI) that allow communication between the human brain and external

[59] For example, Jaušovec, Norbert/Pahor, Anja: Increasing intelligence. London 2017.

[60] See Shah-Basak, Priyanka P./Hamilton, Roy H.: Cognitive enhancement using noninvasive brain simulation: weighing opportunity, feasibility, and risk. In: Ter Meulen, Ruud/Mohamed, Ahmed D./Hall, Wayne (ed.): Rethinking Cognitive Enhancement. Oxford 2017, pp. 125-149.

[61] See Antal, Andrea/Luber, Bruce/Brem, Anna-Katharine/Bikson, Marom/Brunoni, Andre R./Kadosh, Roi Cohen/Paulus, Walter: Non-invasive brain stimulation and neuroenhancement. In: Clinical Neurophysiology Practice, 7, 2022, pp. 146-165.

[62] Brunyé, Tad T./Brou, Randy/Doty, Tracy J./Gregory, Frederick D./Hussey, Erika K./Lieberman, Harris R./Loverro, Kari L./Mezzacappa, Elizabeth p./Neumeier, William H./Patton, Debra J./Soares, Jason W./Thomas, Thaddeus P./Yu, Alfred B.: A Review of US Army Research Contributing to Cognitive Enhancement in Military Contexts. In: Journal of Cognitive Enhancement, 4/4, 2020, pp. 453-468.

[63] Attiah, Mark: The use of brain stimulation technology for cognitive enhancement and the potential for addiction. In: Ter Meulen, Ruud/Mohamed, Ahmed D./Hall, Wayne (ed.): Rethinking Cognitive Enhancement. Oxford 2017, pp. 150-163.

technologies, surgery to place implants is also needed.[64] [65] Due to this high level of invasiveness and risks associated with surgeries, these methods are not (readily) available to the general public but currently mostly used for medical treatment. However, they are at the centre of public debate due to prominent companies working on BCI technologies.[66]

Effectiveness of those enhancement methods

While pharmacological enhancement is already quite frequently applied[67], invasive brain stimulation techniques as well as brain-computer interfaces are more effortful (i.e. needing surgery and advanced brain implants) and, thus, not easily usable by healthy humans. Importantly, for all of those methods, substantial empirical evidence of their effectiveness in enhancing cognition is lacking.[68] [69] For some cognitive abilities, in some individuals, and through some studies, positive indications of cognitive enhancement due to methods such as pharmacological enhancement and non-invasive brain stimulation were found, but the overall effectiveness is highly questionable.[70] The effectiveness of invasive brain stimulation and brain-computer interfaces in healthy individuals is undetermined due to the inherent risks associated with such studies.

[64] For example, Bostrom, Nick/Sandberg, Anders: Cognitive enhancement: methods, ethics, regulatory challenges. In: Science and Engineering Ethics, 15, 2009, pp. 311-341.

[65] For example, Hramov, Alexander E./Maksimenko, Vladimir A./Pisarchik, Alexander N.: Physical principles of brain–computer interfaces and their applications for rehabilitation, robotics and control of human brain states. In: Physics Reports, 918, 2021, pp. 1-133.

[66] For example, see Neuralink by Elon Musk.

[67] See Smith, Elizabeth M./Farah, Martha J.: Are prescription stimulants "smart pills"? The epidemiology and cognitive neuroscience of prescription stimulant use by normal healthy individuals. In: Psychological Bulletin, 137/5, 2011, pp. 717-741.

[68] For example, Jaušovec, Norbert/Pahor, Anja: Increasing intelligence. London 2017.

[69] For example, Repantis, Dimitris/Schlattmann, Peter/Laisney, Oona/Heuser, Isabella: Modafinil and methylphenidate for neuroenhancement in healthy individuals: a systematic review. In: Pharmacological Research, 62, 2010, pp. 187-206.

[70] See recent review, Grinschgl, Sandra/Ninaus, Manuel/Wood, Guilherme/Neubauer, Aljoscha C.: To enhance or not to enhance: A debate about cognitive enhancement from a psychological and neuroscientific perspective. Unpublished manuscript.

Smith and Farah (2011)[71] also emphasised that for some people positive effects can be observed during some tasks due to the intake of drugs. Repantis et al. (2010)[72] suggested an inverted U-shape function depicting the effectiveness of pharmacological enhancement. This means that depending on individuals' baseline level of certain neurotransmitters, the intake of medication might be more or less effective. So far, to my best knowledge, no cognitive enhancement research has taken into account such individual differences and, thus, they should be investigated in the future.

At the moment no general conclusions about the effectiveness of drug use for healthy individuals can be drawn[73], also because most studies only include small samples and, thus, lack statistical power.[74] The effectiveness of enhancement might even be overestimated due to publication bias.[75] Furthermore, it is difficult to transfer findings from laboratory research to the real world.[76] [77] Thus, much more additional research is necessary to make strong claims about the effectiveness of cognitive enhancement in the real world.

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[71] Smith, Elizabeth M./Farah, Martha J.: Are prescription stimulants "smart pills"? The epidemiology and cognitive neuroscience of prescription stimulant use by normal healthy individuals. In: Psychological Bulletin, 137/5, 2011, pp. 717-741.

[72] Repantis, Dimitris/Schlattmann, Peter/Laisney, Oona/Heuser, Isabella: Modafinil and methylphenidate for neuroenhancement in healthy individuals: a systematic review. In: Pharmacological Research, 62, 2010, pp. 187-206.

[73] See Hills, Thomas/Hertwig, Ralph: Why Aren't We Smarter Already: Evolutionary Trade-Offs and Cognitive Enhancements. In: Current Directions in Psychological Science, 20/6, 2011, pp. 373-377.

[74] See De Jongh, Reinoud: Overclocking the brain? The potential and limitations of cognition-enhancing drugs. In: Ter Meulen, Ruud/Mohamed, Ahmed D./Hall, Wayne (ed.): Rethinking Cognitive Enhancement. Oxford 2017, pp. 37-56.

[75] See Smith, Elizabeth M./Farah, Martha J.: Are prescription stimulants "smart pills"? The epidemiology and cognitive neuroscience of prescription stimulant use by normal healthy individuals. In: Psychological Bulletin, 137/5, 2011, pp. 717-741.

[76] Antal, Andrea/Luber, Bruce/Brem, Anna-Katharine/Bikson, Marom/Brunoni, Andre R./Kadosh, Roi Cohen/Paulus, Walter: Non-invasive brain stimulation and neuroenhancement. In: Clinical Neurophysiology Practice, 7, 2022, pp. 146-165.

[77] Smith, Elizabeth M./Farah, Martha J.: Are prescription stimulants "smart pills"? The epidemiology and cognitive neuroscience of prescription stimulant use by normal healthy individuals. In: Psychological Bulletin, 137/5, 2011, pp. 717-741.

Side effects and risks

In addition to missing evidence on the effectiveness of cognitive enhancement, side effects und long-term risks of both pharmacological enhancement and brain stimulation as well as BCI technologies are also mainly unexplored. Multiple researchers suggest a gain-loss asymmetry of cognitive enhancement[78] [79] [80]: an increase in cognitive functions for one specific area due to cognitive enhancement might come with a decrease in another area. Thus, if cognitive enhancement provides a benefit in one area, it might also induce negative side effects for another area. Hills and Hertwig (2011)[81] argue that psychological research is indispensable to identify which individual's enhancement is most effective and in which environments, and to investigate which cognitive functions might be vulnerable in the gain-loss asymmetry.

Additionally, for pharmacological enhancement via smart drugs or illicit drugs, there may be a risk of addiction as well as unexplored negative effects on healthy brains due to regular off-label drug intake.[82] Studies on repeated drug intake by healthy individuals are, however, lacking.[83] Thus, the risks of regular off-label drug intake remain unknown.

For (invasive) brain stimulation methods, the risks might be as or even more severe: first, the surgery to implant a brain chip comes with several risks such

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[78] For example, Pustovrh, Tony/Mali, Franc/Arnaldi, Simone: Are Better Workers Also Better Humans? On Pharmacological Cognitive Enhancement in the Workplace and Conflicting Societal Domains. In: NanoEthics, 12/3, 2018, pp. 301-313.

[79] See *net-zero concept*, Colzato, Lorenza p./Hommel, Bernhard/Beste, Christian: The Downsides of Cognitive Enhancement. In: The Neuroscientist, 27/4, 2021, pp. 322-330.

[80] Hills, Thomas/Hertwig, Ralph: Why Aren't We Smarter Already: Evolutionary Trade-Offs and Cognitive Enhancements. In: Current Directions in Psychological Science, 20/6, 2011, pp. 373-377.

[81] Hills, Thomas/Hertwig, Ralph: Why Aren't We Smarter Already: Evolutionary Trade-Offs and Cognitive Enhancements. In: Current Directions in Psychological Science, 20/6, 2011, pp. 373-377.

[82] For example, Massie, Charles F./Yamga, Eric M./Boot, Brendon P.: Neuroenhancement: a call for better evidence on safety and efficacy. In: Ter Meulen, Ruud/Mohamed, Ahmed D./Hall, Wayne (ed.): Rethinking Cognitive Enhancement. Oxford 2017, pp. 57-68.

[83] Repantis, Dimitris/Schlattmann, Peter/Laisney, Oona/Heuser, Isabella: Modafinil and methylphenidate for neuroenhancement in healthy individuals: a systematic review. In: Pharmacological Research, 62, 2010, pp. 187-206.

as possible infections or other complications. Second, the enhanced individual is highly dependent on the company or organisation providing the brain chip. If, for instance, the company goes bankrupt, the question arises as to who is continuing to monitor the brain chip and take responsibility for it. Third, individuals with implants might be susceptible to cyberattacks which might manipulate implants.[84] [85] These are just some risks that brain implants used for deep brain stimulation or BCIs, for instance, might entail. Taken together, invasive brain stimulation and BCI methods seem – in the current state of research and medical possibilities – too risky to be used unless they are medically necessary.

As another – more general – risk of cognitive enhancement, Birnbacher (2019)[86] suggests an overconfidence in one's own abilities. While enhancement itself might not be particularly effective, individuals might believe that it is and overestimate their abilities. This is particularly dangerous in high-risk situations such as in the military or other security forces. If, for instance, soldiers overestimate their abilities, they might put themselves at risk, but also their comrades and entire military operations.

Critically, it seems that the media is promoting an overly optimistic view of enhancement – at least when it comes to specific enhancement methods. In a study, Partridge et al. (2011)[87] observed that newsprint media depicts pharmacological enhancement as more common than it actually is. Furthermore, the risks of this form of enhancement seem to be neglected. Birnbacher

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[84] See brainjacking in: Pycroft, Laurie/Boccard, Sandra G./Owen, Sarah L. F./Stein, John F./Fitzgerald, James J./Green, Alexander L./Aziz, Tipu Z.: Brainjacking: Implant Security Issues in Invasive Neuromodulation. In: World Neurosurgery, 92, 2016, pp. 454-462.

[85] See *brainjacking* in: Merkel, Reinhard: Neuroenhancement, Autonomie und das Recht auf mentale Selbstbestimmung. In: Viertbauer, Klaus/Kögerler, Reinhart (ed.): Neuroenhancement: die philosophische Debatte. Berlin 2019, pp. 43-88.

[86] Birnbacher, Dieter: Neuroenhancement – eine ethische Sicht. In: Viertbauer, Klaus/Kögerler, Reinhart (ed.): Neuroenhancement: die philosophische Debatte. Berlin 2019, pp. 18-42.

[87] Partridge, Bradley J./Bell, Stephanie K./Lucke, Jayne C./Yeates, Sally/Hall, Wayne D.: Smart Drugs "As Common As Coffee": Media Hype about Neuroenhancement. In: PLoS ONE, 6/11, 2011, e28416.

(2019)[88] points out that such an overly optimistic view of enhancement can also lead to the wasting of resources. For instance, individuals – or even organisations such as the military – might spend money on useless enhancement tools, or research efforts might be made that are not promising of success.

Alternative – potentially more promising – forms of cognitive enhancement

As I outlined before, the described enhancement methods seem less promising than oftentimes suggested. Furthermore, they might entail severe risks for healthy humans. Thus, from a psychological and neuroscientific perspective I would – in the current state of research – not recommend applying those forms of enhancement. Furthermore, I would urge both laboratory and applied research to focus on other – potentially more promising – cognitive enhancement methods. Psychological research showed that those known as active enhancement methods which entail a certain effort by the user are more accepted by laypersons than passive methods such as pharmacological enhancement and brain stimulation methods for which the user's effort might be smaller.[89] Most importantly, active cognitive enhancement methods might entail fewer risks.

Active enhancement includes rather effortful cognitive enhancement methods such as working memory training or neurofeedback to learn how to train one's brain activity. While the effectiveness of those methods is also rather questionable in the current state of research,[90] active enhancement methods might foster individual's well-being by increasing their autonomy and moti-

[88] Birnbacher,Dieter: Neuroenhancement – eine ethische Sicht. In: Viertbauer, Klaus/ Kögerler, Reinhart (ed.): Neuroenhancement: die philosophische Debatte. Berlin 2019, pp. 18-42.

[89] See Grinschgl, Sandra/Berdnik, Anna-Lena/Stehling, Elisabeth/Hofer, Gabriela/ Neubauer, Aljoscha C.: Who wants to enhance their cognitive abilities? Potential predictors of the acceptance of cognitive enhancement. In: Journal of Intelligence, 11/6, 2023, p. 109.

[90] For example, see Jaušovec, Norbert/Pahor, Anja: Increasing intelligence. London 2017.

vation.[91] Furthermore, no dangerous side effects or long-term risks such as brain damage or infection due to surgery can be expected from them. I would therefore suggest to rather put scientific and public effort into the further development of these active enhancement methods as a potential means to enhance humans' cognition than to rely on highly risky methods such as pharmacological enhancement and brain stimulation.

Laypersons' views on cognitive enhancement methods and users of cognitive enhancement

While there are certain populations who are known to (at least to some degree) apply cognitive enhancement methods such as "neurohackers"[92] and university students (when it comes to pharmacological enhancement[93]), there are only a few studies which empirically investigated laypersons' views on cognitive enhancement methods as well as the characteristics of enhancement users.

Generally, the public's view on enhancement is rather negative.[94] [95] In an empirical study, pharmacological enhancement was viewed more negatively than brain stimulation, which might be due to the greater familiarity with smart drugs than brain stimulation and, thus, more negative views among

[91] See Grinschgl, Sandra/Ninaus, Manuel/Wood, Guilherme/Neubauer, Aljoscha C.: To enhance or not to enhance: A debate about cognitive enhancement from a psychological and neuroscientific perspective. Unpublished manuscript.

[92] See Wexler, Anna: The Social Context of "Do-It-Yourself" Brain Stimulation: Neurohackers, Biohackers, and Lifehackers. In: Frontiers in Human Neuroscience, 11, 2017, p. 224.

[93] For example, Maier, Larissa J./Ferris, Jason A./Winstock, Adam R.: Pharmacological cognitive enhancement among non-ADHD individuals – A cross-sectional study in 15 countries. In: International Journal of Drug Policy, 58, 2018, pp. 104-112.

[94] Dijkstra, Anne M./Schuijff, Mirjam: Public opinions about human enhancement can enhance the expert-only debate: A review study. In: Public Understanding of Science, 25/5, 2016, pp. 588-602.

[95] See Grinschgl, Sandra/Tawakol, Zadaf/Neubauer, Aljoscha C.: Human enhancement and personality: A new approach towards investigating their relationship. In: Heliyon, 8, 2022, p. e09359.

the public.[96] [97] Non-users of enhancement, especially, seem to have concerns about enhancement, relating to its medical safety and fairness.[98]

Additionally, for pharmacological enhancement, Bergström and Lynöe (2008)[99] showed that natural substances are more accepted in enhancement than pharmaceuticals. Relatedly, Conrad et al. (2019) showed a greater approval of pharmacological enhancement for others than for oneself.[100] Moreover, approval of pharmacological enhancement for oneself was greater when it was presented in an athlete context rather than an employee or student context.

A study conducted by McCabe et al. (2005) surveyed college students across the US regarding their non-medical drug use.[101] The findings indicated that drug use was more prevalent among male students, white students, members of fraternities and sororities and those with lower average grades. Additionally, the survey revealed that the use of such drugs was more common in colleges located in the northeastern US and at institutions with highly competitive admission criteria. Pharmacological enhancement behaviour was also shown to be oftentimes accompanied by other risky behaviours such as binge drinking and the intake of illicit drugs – which is especially dangerous as pharmaceuticals might detrimentally interact with other substances. Inter-

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[96] Grinschgl, Sandra/Tawakol, Zadaf/Neubauer, Aljoscha C.: Human enhancement and personality: A new approach towards investigating their relationship. In: Heliyon, 8, 2022, p. e09359.

[97] See Schönthaler, Elena M. D./Hofer, Gabriela/Grinschgl, Sandra/Neubauer, Aljoscha C.: Super-Men and Wonder-Women: the Relationship Between the Acceptance of Self-enhancement, Personality, and Values. In: Journal of Cognitive Enhancement, 6, 2022, pp. 358-372.

[98] See study on pharmacological enhancement, Schelle, Kimberly J./Faulmüller, Nadira/Caviola, Lucius/Hewstone, Miles: Attitudes toward pharmacological cognitive enhancement: a review. In: Frontiers in Systems Neuroscience, 8, 2014, p. 53.

[99] Bergström, Lena/Lynöe, Niels: Enhancing concentration, mood and memory in healthy individuals: An empirical study of attitudes among general practitioners and the general population. In: Scandinavian Journal of Public Health, 36/5, 2008, pp. 532-537.

[100] Conrad, Erin C./Humphries, Stacey/Chatterjee, Anjan: Attitudes Toward Cognitive Enhancement: The Role of Metaphor and Context. In: AJOB Neuroscience, 10/1, 2019, pp. 35-47.

[101] McCabe, Sean E./Knight, John R./Teter, Christian J./Wechsler, Henry: Non-medical use of prescription stimulants among US college students: Prevalence and correlates from a national survey. In: Addiction, 100/1, 2005, pp. 96-106.

estingly, this study shows that both individual differences with regard to the characteristics of students (e.g. their gender) and surrounding factors (e.g. being part of fraternities or certain highly competitive colleges) might foster the intake of drugs for pharmacological enhancement.

A more recent study by Bagusat et al. (2018) found that higher perceived stress levels are linked to the use of enhancement drugs.[102] However, Mayor et al. (2020) showed that individuals' competitiveness is not linked to attitudes toward pharmacological enhancement.[103] This suggests that stressful situations, rather than individuals' competitiveness, may be one factor driving the use of these drugs. With regard to microdosing, Cameron et al. (2020) observed that men are almost twice as likely to use this form of enhancement than women.[104] This finding is further supported by a study from Conrad et al. (2019) showing a greater approval of pharmacological enhancement by men than women.[105] In contrast, an Austrian survey showed no differences between male and female students in the respective prevalences.[106]

In an experimental study, Maier et al. (2015) compared healthy individuals who are regular users of pharmacological enhancement to a control group against different cognitive and personality measures.[107] While the two groups

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[102] Bagusat, Christiana/Kunzler, Angela/Schlecht, Jennifer/Franke, Andreas G./Chmitorz, Andrea/Lieb, Klaus: Pharmacological neuroenhancement and the ability to recover from stress – a representative cross-sectional survey among the German population. In: Substance Abuse Treatment, Prevention, and Policy, 13/1, 2018, p. 37.

[103] Mayor, Eric/Daehne, Maxime/Bianchi, Renzo: The dark triad of personality and attitudes toward cognitive enhancement. In: BMC Psychology, 8, 2020, pp. 1-12.

[104] Cameron, Lindsay P./Nazarian, Angela/Olson, David E.: Psychedelic Microdosing: Prevalence and Subjective Effects. In: Journal of Psychoactive Drugs, 52/2, 2020, pp. 113-122.

[105] Conrad, Erin C./Humphries, Stacey/Chatterjee, Anjan: Attitudes Toward Cognitive Enhancement: The Role of Metaphor and Context. In: AJOB Neuroscience, 10/1, 2019, pp. 35-47.

[106] Dietz, Pavel/Iberl, Benedikt/Schuett, Emanuel/Van Poppel, Mireille/Ulrich, Rolf/Sattler, Matteo C.: Prevalence Estimates for Pharmacological Neuroenhancement in Austrian University Students: Its Relation to Health-Related Risk Attitude and the Framing Effect of Caffeine Tablets. In: Frontiers in Pharmacology, 9, 2018, p. 494.

[107] Maier, Larissa J./Wunderli, Michael D./Vonmoos, Matthias/Römmelt, Andreas T./Baumgartner, Markus R./Seifritz, Erich/Schaub, Michael P./Quednow, Boris B.: Pharmacological Cognitive Enhancement in Healthy Individuals: A Compensation for Cognitive Deficits or a Question of Personality? In: PLoS One, 10/6, 2015, e0129805

mostly showed no differences in the cognitive tasks, users of pharmacological enhancement showed a higher tendency towards novelty seeking, negativistic and antisocial personality traits, as well as Machiavellianism than the control group. Furthermore, they showed lower levels of social reward dependence and had fewer social contacts in comparison to the control group. No differences in narcissism between the groups were observed. Mayor et al. (2020) observed similar results with regard to the Dark Triad traits (grandiose narcissism, psychopathy and Machiavellianism) and attitudes towards pharmacological enhancement.[108] While narcissism and psychopathy were not related to positive attitudes towards this form of enhancement, increased Machiavellianism was related to more positive attitudes. Taken together, certain personal characteristics such as Dark Triad traits might impact the willingness to use pharmacological enhancement.

When it comes to brain stimulation, researchers express greater reservations about using tDCS for cognitive enhancement than in its application in clinical or research contexts.[109] Interestingly, about one third of these participants indicated they would consider using tDCS for enhancement. The likelihood of wanting to use tDCS for enhancement was positively associated with the belief in its effectiveness, while heightened ethical concerns were linked to a reduced willingness to pursue this form of enhancement.

These studies give an initial impression of individuals' views on pharmacological enhancement and brain stimulation methods. Certain surrounding factors as well as personal characteristics might foster the willingness to apply specific enhancement methods.

Not only focusing on one enhancement method, but instead incorporating a range of different passive and active enhancement methods, Grinschgl et al. (2023) observed that people's intelligence does not predict the acceptance

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[108] Mayor, Eric/Daehne, Maxime/Bianchi, Renzo: The dark triad of personality and attitudes toward cognitive enhancement. In: BMC Psychology, 8, 2020, pp. 1-12.

[109] Riggall, Kate/Forlini, Cynthia/Carter, Adrian/Hall, Wayne/Weier, Megan/Partridge, Brad/Meinzer, Marcus: Researchers' perspectives on scientific and ethical issues with transcranial direct current stimulation: An international survey. In: Scientific Reports, 5/1, 2015, p. 10618.

of either enhancement type.[110] Acceptance of passive enhancements was linked to a younger age[111] , less conscientiousness and a stronger interest in science fiction[112]. For active enhancements, acceptance was associated with a younger age, elevated openness and a greater interest in science fiction.

Taken together, these (mostly psychological) studies highlight laypersons' views on cognitive enhancement and characteristics of potential enhancement users. However, additional research is necessary to test a range of different personal characteristics and environmental factors in order to find strong predictors of the willingness to apply cognitive enhancement. Knowing which persons might enhance themselves can help in targeting those persons to inform them about the potential up- and downsides of cognitive enhancement. Additionally, in applying cognitive enhancement within organisations such as the military, it is important to know which individuals might be willing to use those methods and which are not.

3. Current challenges – what can and should be done with regard to cognitive enhancement

In public discussions pertaining to cognitive enhancement, it seems that the effectiveness of different methods is rather over-estimated[113] [114] and psycho-

[110] Grinschgl, Sandra/Berdnik, Anna-Lena/Stehling, Elisabeth/Hofer, Gabriela/Neubauer, Aljoscha C.: Who wants to enhance their cognitive abilities? Potential predictors of the acceptance of cognitive enhancement. In: Journal of Intelligence, 11/6, 2023, p. 109.

[111] See also Breivik, Gunnar/Sagoe, Dominic/Loland, Sigmund: Personality and willingness towards performance enhancement and body modification: A cross-sectional survey of a nationally representative sample of Norwegians. In: Frontiers in Sports and Active Living, 4, 2022, p. 906634.

[112] See also Koverola, Mika/Kunnari, Anton/Drosinou, Marianna/Palomäki, Jussi/Hannikainen, Ivar R./Jirout Košová, Michaela/Kopecký, Robin/Sundvall, Jukka/Laakasuo, Michael: Treatments approved, boosts eschewed: Moral limits of neurotechnological enhancement. In: Journal of Experimental Social Psychology, 102, 2022, p. 104351.

[113] For example, Kourany, Janet A.: Human Enhancement: Making the debate more productive. In: Erkenntnis, 79, 2014, pp. 981-998.

[114] For example, Partridge, Bradley J./Bell, Stephanie K./Lucke, Jayne C./Yeates, Sally/Hall, Wayne D.: Smart Drugs "As Common As Coffee": Media Hype about Neuroenhancement. In: PLoS ONE, 6/11, 2011, e28416.

logical as well as neuroscientific research is misinterpreted or ignored.[115] [116] This could, in return, also lead to an overestimation of enhancement possibilities in critical governmental organisations, such as security forces (i.e. the police, military). Potentially, those might aim to apply enhancement to supposedly increase performance among their employees (as, for instance, has at least been tested in the US army)[117], without actually understanding the up- and downsides as derived from scientific studies.

In fact, what can be done for healthy individuals using the outlined cognitive enhancement methods at the moment is almost nothing. Pharmacological enhancement has shown, at most, moderate effects on cognitive abilities[118] and entails many open questions such as the risks of addiction and consequences of repeated drug intake. Similarly, non-invasive brain stimulation has negligible effects on cognition for healthy individuals.[119] Invasive brain stimulation techniques come with severe risks as they require surgery and a heavy reliance on the brain chip providers. Therefore, in the current state of research and technical as well as medical possibilities, I would advise against applying those methods or planning to apply them in the foreseeable future – for the general public but also for organisations like the military.

Before a broad application of cognitive enhancement may be rationally warranted, the following steps should be taken from a psychological and neuroscientific perspective:

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[115] See also Ter Meulen, Ruud/Mohamed, Ahmed D./Hall, Wayne: Introduction. In: Ter Meulen, Ruud/Mohamed, Ahmed D./Hall, Wayne (ed.): Rethinking Cognitive Enhancement. Oxford 2017, pp. 3-14.

[116] See also Pauen, Michael: Autonomie und Enhancement. In: Viertbauer, Klaus/Kögerler, Reinhart (ed.): Neuroenhancement: die philosophische Debatte. Berlin 2019, pp. 89-114.

[117] Brunyé, Tad T./Brou, Randy/Doty, Tracy J./Gregory, Frederick D./Hussey, Erika K./Lieberman, Harris R./Loverro, Kari L./Mezzacappa, Elizabeth p./Neumeier, William H./Patton, Debra J./Soares, Jason W./Thomas, Thaddeus P./Yu, Alfred B.: A Review of US Army Research Contributing to Cognitive Enhancement in Military Contexts. In: Journal of Cognitive Enhancement, 4/4, 2020, pp. 453-468.

[118] For example, Repantis, Dimitris/Schlattmann, Peter/Laisney, Oona/Heuser, Isabella: Modafinil and methylphenidate for neuroenhancement in healthy individuals: a systematic review. In: Pharmacological Research, 62, 2010, pp. 187-206.

[119] Jaušovec, Norbert/Pahor, Anja: Increasing intelligence. London 2017.

a) More research is needed to explore individual differences with regard to the effectiveness of cognitive enhancement methods. For instance, whether certain enhancement methods might be effective for some individuals or groups, but not for others, has remained mostly unexplored.
b) For the safe application of cognitive enhancement, longitudinal studies are necessary to explore the potential long-term effects. For instance, the consequences of repeated drug intake, such as the risk of addiction and potential brain damage, are unknown. Some methods should only be applied under medical supervision and regulations/guidelines by, for instance, the government or World Health Organization.
c) For both step a) and b) it is important to carefully distinguish between clinical research and enhancement research using healthy individuals as samples. The direct transfer of findings in one area to the other might prove a dangerous fallacy.[120] Similarly, we – as researchers but also central actors among the public – must work towards correcting the misinterpretation of neuroscientific and medical findings. Such avoidance of misinterpretation is especially important for governmental organisations such as the military.[121]
d) Ethical considerations about successful (i.e. effective) enhancement need to be explored and taken into account in the development of those methods. For instance, the question arises as to who has access to which enhancement methods as well as to the reasons why those would be applied (e.g. risk of coercion). For a number of additional, important ethical questions, see Neubauer (2021).[122] Interestingly, Gyngell and Easteal (2015)[123] even suggested that cognitive enhance-

[120] For a deeper exploration of this problem, see Grinschgl, Sandra/Ninaus, Manuel/Wood, Guilherme/Neubauer, Aljoscha C.: To enhance or not to enhance: A debate about cognitive enhancement from a psychological and neuroscientific perspective. Unpublished manuscript.

[121] See Sturma, Dieter: Subjekt sein: Über Selbstbewusstsein, Selbstbestimmung und Enhancement. In: Viertbauer, Klaus/Kögerler, Reinhart (ed.): Neuroenhancement: die philosophische Debatte. Berlin 2019, pp. 115-147.

[122] Neubauer, Aljoscha C.: The future of intelligence research in the coming age of artificial intelligence – With a special consideration of the philosophical movements of trans- and posthumanism. In: Intelligence, 87, 2021, p. 101563.

[123] Gyngell, Chris/Easteal, Simon: Cognitive Diversity and Moral Enhancement. In: Cambridge Quarterly of Healthcare Ethics, 24/1, 2015, pp. 66-74.

ment should go hand in hand with moral enhancement, as cognitive enhancement might increase diversity among people whose acceptance requires a higher morality.

e) Finally, to tackle the topic of cognitive enhancement, different disciplines need to work together and research enhancement-related issues. Not only psychologists and neuroscientists, but medical doctors, technicians, philosophers and other researchers should also work together to paint a comprehensive picture of cognitive enhancement.

Only if those steps are taken and enhancement methods are shown to be effective as well as safe for the targeted group, it might be advisable to think about applying cognitive enhancement in critical institutions such as the military. However, I would also argue that efforts towards (passive) cognitive enhancement methods such as pharmacological enhancement and brain stimulation might not be successful at all. Thus, it is questionable whether research efforts should be made in that direction in the first place.

4. Outlook – Cognitive enhancement in the short, medium and long term

In the previous sections of this chapter, I presented the current state of cognitive enhancement methods from a psychological and neuroscientific perspective. Of course, I cannot foresee the future, but I want to provide some suggestions on future developments of cognitive enhancement.

Short term (until 2025)

In the short term, I do not expect scientific, technical and/or medical advancements which would have the potential for effective cognitive enhancement. Instead, I hope that in the coming years we – as a scientific community – will work on reducing misinterpretations of scientific findings and presenting scientifically accurate evidence to the public with regard to cognitive enhancement. As we can see from this book, governmental organisations such as the military are already thinking about this topic; thus, now is the time to correct views on enhancement and to properly disseminate respective research findings for this purpose.

Medium term (until 2030)

For the medium term, I believe that this (i.e. correcting views on enhancement) needs to continue. Furthermore, I believe that in the coming years more research on cognitive enhancement will be done – both by universities and commercial companies – and some of my points raised in the previous section (3.) will potentially be addressed. Nevertheless, I cannot imagine that the forms of cognitive enhancement described here will actually become effective and – even more importantly – safe by the year 2030.

Long term (from 2030)

I do not know what the distant future will look like, but I want to mention two (of many) possible scenarios.

First, the substantial enhancement of human cognition might still not be possible by technological and medical means. At the same time, AI systems will probably gain more and more abilities. Thus, in the distant future, we – as humans – might need to adapt to those technologies and learn how to successfully incorporate them into our lives. Due to the use of AI, we might be able to perform more accurately, faster and more reliably in the future. Thus, AI systems could be an indirect way to enhance human performance – even more so in the future than already is the case.[124]

Second, we could indeed imagine effective cognitive enhancement methods in the future. For instance, through pharmacological enhancement we might become extremely attentive and be able to absorb large amounts of information in a short time frame. But what would that mean for individuals, society and governmental organisations such as the military? As mentioned in section 3, successful enhancement comes with many ethical questions that would need to be tackled. For instance, the question arises as to who has access to enhancement methods and how expensive is it to use them? Who

[124] See Grinschgl, Sandra/Neubauer, Aljoscha C.: Supporting cognition with modern technology: Distributed cognition today and in an AI-enhanced future. In: Frontiers in Artificial Intelligence, 5, 2022, p. 908261.

can decide whether a person gets enhanced? Are humans losing their autonomy, free will and motivation if they get enhanced?

These are just a few of the many ethical questions that successful enhancement would entail. In a techno-optimistic future as described by Makridis (2013)[125], pharmaceuticals might increase employees' productivity and military troops might be enhanced. Pustovrh et al. (2018) suggest that pharmacological enhancement might make people become more successful, capable and, thus, make them more competitive in rapidly changing work environments.[126] However, so far, this seems to be an optimistic fantasy.

I believe that even if enhancement becomes effective in the future, there are many difficult ethical questions that still need to be tackled before cognitive enhancement should be made available to the public or applied within governmental organisations such as the military.

5. Recommendations and conclusions

Taken together, I want to endorse a less positive outlook on cognitive enhancement than is oftentimes portrayed in transhumanist publications but also in other media reports. More interdisciplinary research is needed to test potentially promising cognitive enhancement methods and – most importantly – to test short- and long-term risks of those methods as well as to develop safe protocols and regulations on their use.

In the current state of research, the promises of cognitive enhancement methods such as pharmacological enhancement and brain stimulation seem overestimated, which could lead to dangerous fallacies. For instance, enhancement might be applied – but without creating performance gains and instead only generating risks. This should be avoided. Thus, I also advise against applying those methods in critical institutions at this time – such as the police and military. However, even if not effective, the European Union

[125] Makridis, Christos: Converging Technologies: A Critical Analysis of Cognitive Enhancement for Public Policy Application. In: Science and Engineering Ethics, 19, 2013, pp. 1017-1038.

[126] Pustovrh, Tony/Mali, Franc/Arnaldi, Simone: Are Better Workers Also Better Humans? On Pharmacological Cognitive Enhancement in the Workplace and Conflicting Societal Domains. In: NanoEthics, 12/3, 2018, pp. 301-313.

and governments themselves should think about stricter regulations on applying enhancements – potentially similar to doping regulations in sports.

As mentioned at the beginning of this chapter, humans have always tried to enhance themselves.[127] Thus, they will continue to do so. However, instead of applying passive enhancement methods as described in this chapter (e.g. pharmacological enhancement, brain stimulation), I would recommend putting effort into active methods such as cognitive training. Cognitive training may have the potential to both increase people's cognition (at least for certain cognitive tasks) and well-being, while being accompanied by negligible risks. Indeed, cognitive training has also been tested in the military. Blacker et al. (2019) outline some practical considerations for testing and implementing cognitive enhancement within the military.[128] Most importantly, standardised experimental research designs are needed to test the effectiveness of different cognitive enhancement methods within the military context.

Finally, I want to stress again that potentially successful cognitive enhancement does not end with its development but also requires addressing many more open questions for which interdisciplinary contributions are necessary. Thus, in order for cognitive enhancement to be a positive outcome for humanity, psychology, neuroscience, technology-related fields, medicine, philosophy, sociology and other fields need to work together.

[127] See Pauen, Michael: Autonomie und Enhancement. In: Viertbauer, Klaus/Kögerler, Reinhart (ed.): Neuroenhancement: die philosophische Debatte. Berlin 2019, pp. 89-114.

[128] Blacker, Kara J./Hamilton, Joseph/Roush, Grant/Pettijohn, Kyle A./Biggs, Adam T.: Cognitive training for military application: a review of the literature and practical guide. In: Journal of Cognitive Enhancement, 3, 2019, 30-51.

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De Jongh, Reinoud: Overclocking the brain? The potential and limitations of cognition-enhancing drugs. In: Ter Meulen, Ruud/Mohamed, Ahmed D./Hall, Wayne (ed.): Rethinking Cognitive Enhancement. Oxford 2017, pp. 37-56.

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