Human augmentation to deliver an enhanced and resilient people capability for Defence

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ABSTRACT

From first tools, to flight, to advances in medicine and biotechnology, enhancing our innate abilities has been a constant goal and militaries the world over have long sought to advance the limits of human performance in their warfighters. Human augmentation (HA) encompasses a wide range of technologies that straddle a diversity of scientific disciplines and maturity levels, including wearable assistive technologies such as exoskeletons, neurotechnology, pharmacology, telexistence and genetics. Recent and rapid advances in life sciences and biotechnology and the convergence of fields such as artificial intelligence, robotics and medicine present us with a radically different opportunity for optimising and enhancing human performance. HA can be considered a potentially important strategy underpinning our ability to fight and win wars, by making soldiers more lethal and better able to survive. This paper is based on the HA thematic session held at the 6th International Congress on Soldiers' Physical Performance (ICSPP) in London in 2023. It considers aspects of HA of interest to participating nations and provides a state-of-the-art review of HA from a military perspective by experts engaged in this area. It considers the development of capability requirements, ethical, legal and social aspects and candidate HA technologies, one with ancient roots but modern applications for Defence (pharmacological augmentation) and one emerging area (non-invasive brain stimulation). HA offers a number of benefits, opportunities and challenges to the Defence community. Deployment of these technologies must take place within the boundaries of a nation's core values and beliefs, the rules-based international order and the freedoms that underpin their militaries' moral and ethical foundations.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Warfighting remains, at its core, a human endeavour and militaries have long sought to advance the limits of human performance to maximise fighting power.

WHAT THIS STUDY ADDS

⇒ This targeted review considers the topic of human augmentation (HA) in a Defence context, drawing together current insights from an international team of experts in this area.

⇒ The authors present principles for the development of capability requirements, prioritisation of technologies and a framework for considering the ethical, legal and social aspects of HA.

⇒ Two candidate HA technologies are considered in more detail, pharmacological augmentation and non-invasive brain stimulation, to illustrate both what we know and those areas that require further research and consideration.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ By providing a structure for the identification and ethical deployment of HA interventions, this review paves the way for a move from concepts and research towards implementation of these technologies in an operational environment, in order to optimise and enhance the protection and performance of military personnel.

INTRODUCTION

From first tools, to flight, to advances in medicine and biotechnology, enhancing our innate abilities has been a constant goal and militaries the world over have long sought to advance the limits of human performance in their warfighters. For the purposes of this paper, human augmentation (HA) is defined as 'the use of science or technology to improve human performance'. This definition of HA is agnostic of whether effects are temporary or permanent, invasive or non-invasive and includes both human performance optimisation and human performance enhancement. Human performance optimisation is defined as 'the use of science or technology to improve human performance up to the limit of innate human potential' and includes restoration of task-related declines in performance. Human performance enhancement is defined as 'the use of science or technology to improve human performance beyond the limit of innate human potential, including the addition of capabilities not intrinsic to humans'. HA encompasses a wide range of technologies that straddle a diversity of scientific disciplines and maturity levels, including wearable assistive technologies such as exoskeletons, neurotechnology, pharmacology, telexistence and genetics. Recent and rapid advances in life sciences and biotechnology and the convergence of fields such as artificial intelligence, robotics and medicine present a radically different opportunity for optimising and enhancing human performance.[1]

The war in Ukraine has demonstrated that while technological innovation at pace is vital, warfighting remains, at its core, a human endeavour reliant on human skill, ingenuity, adaptability and motivation, and it remains a bloody and visceral undertaking. HA can be considered, therefore, a potentially important strategy underpinning our ability to fight and win wars, by making soldiers more lethal and better able to survive. To maximise

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this effect, human performance of individuals and teams should be considered across physical, psychological, cognitive, social and behavioural domains. As we move from concepts and research to implementation of these technologies in an operational environment, issues of law, ethics and an understanding of the public appetite for HA in the military will be key, as will the acceptability of *choosing* to augment and of *choosing not* to augment front line military personnel. This paper is based on the HA thematic session held at the 6th International Congress on Soldiers' Physical Performance (ICSPP) London in 2023. It considers aspects of HA of interest to participating nations and provides a state-of-the-art review of HA from a military perspective by experts engaged in this area.

TECHNOLOGICAL INTERVENTIONS

Technological interventions present opportunities for physical and cognitive performance improvement. Defence organisations should implement strategies, for example, horizon scanning and technology watching to identify where technology could be applied to achieve HA. Once potential interventions are identified, exploratory research should be conducted to further develop these concepts and generate the evidence base for HA. A ‘test early, fail fast’ culture will facilitate innovation, recognising that many concepts may not progress beyond the exploratory stage.

Alongside exploratory research, it is essential to understand the capability requirement, that is, what Defence requires its people to do. Capability requirements should be agnostic of the technology and not offer solutions but focus on communicating the Defence need (table 1). Once the requirement is understood, concepts identified through the exploratory research should be investigated to identify if they could enable or support the requirement. This will inform the design of research and will enable the technologies to progress in a direction that meets Defence’s needs.

In line with the principles outlined in Joint Service Publication 912 (Human Factors Integration for Defence Systems),[2] it is essential that the human is considered in the early stages of technology development. This can be achieved by conducting an early human factors assessment of technology concepts.[3] This technology assessment will ensure that risks, assumptions, issues, dependencies and opportunities can be identified early in the development stage and mitigated as part of technology development rather than considered once the technology has matured.

Table 1 Examples of capability requirements for human augmentation

Capability requirement—poor example	Capability requirement—good example
Infantry personnel require an exoskeleton.	Infantry personnel must have the capability to conduct long duration marching carrying the equipment needed to build an observation post. Personnel must be able to sustain themselves in the field for 5 days without resupply. Injury risk must be mitigated.
► Task requirements are not specific. ► Assumes a technology offers benefits to end users. ► The success of technology implementation cannot be measured.	► Task is specific. ► Does not make assumptions about a particular technology or solution. ► Outcome measure is clear (ie, mission success with mitigated injury).

In summary, when considering potential technological interventions, the authors recommend that Defence organisations adopt three core principles: (1) champion innovation, (2) define the capability requirement and (3) adopt a human-centred design approach, which includes ethical, legal and social aspects (ELSA).

ETHICAL, LEGAL AND SOCIAL ASPECTS OF OPERATIONALISING HA

Biotechnology and human enhancement technologies (BHET) is one of the North Atlantic Treaty Organisation's (NATO's) nine priority technology areas.[4] NATO acknowledges that the desire to optimise or enhance military performance also demands caution, care and accountability of those involved in military decision making.[5] An undue bias towards mission success, for example, could result in insufficient attention to the welfare of individuals involved and could threaten the autonomy of personnel and military physicians. Ethics considerations, legal requirements and social concerns should be considered during the development and deployment of HA, particularly enhancement aspects.[6–11] Clear use cases, careful deliberation with stakeholders and a clear governance structure to facilitate Defence policy formation are required.

Defence organisations have an obligation to harness technological interventions, including interventions harnessing novel and emerging science and technology, responsibly, lawfully and ethically, but some countries are known to disregard ELSA. Over the past decade, there has been increasing international awareness of ELSA considerations for military HA. A US Defense Advanced Research Projects Agency (DARPA) -led framework for military HA[12] underpinned subsequent work in this area, including frameworks to evaluate dual-use technology,[6] Canadian[13] and European[14] approaches to ethics of human performance enhancement, a reflection on soldier enhancement by the French Ministry of Armed Forces[15] and a review of HA frameworks by Whetham and colleagues.[11] Most principles focus on ethics, although some include elements of legal and social aspects. In addition, there are several governmental policy statements and NATO reports that in some way or another address ethical, legal and/or social aspects of HA.

From these existing frameworks and documents, core principles may be drawn, each with their own specific elements (discussed below). There has, however, been a lack of progress in developing recommendations on how to address these considerations in a systematic and practical way, and in putting the ethics literature in a Defence context to provide guidance to support HA governance and decision making. A bespoke set of ethics principles plus a means to deliberate the legality and social acceptability of HA technologies in a Defence setting is required. The aim is to provide military decision makers with a bespoke set of ELSA principles to support a systematic and constructive deliberation process for the implementation of HA technologies.

Legal, ethical and social aspects of HA technology development, procurement and deployment

Consideration of legal aspects ideally starts in the early phases of HA research, development and deployment, and continues throughout the process, in strategic decision making and in conversation with legal and medical experts.[16] Four important legal aspects are identified (box 1), requiring proficiency in public international law, international humanitarian law, human rights law and domestic law.

Box 1 Legal aspects

1. What is the legal basis for using this human augmentation (HA) technology or application? Does it impinge on the right to life?
2. Is this HA technology or application necessary, in terms of effectiveness, subsidiarity and proportionality?
3. How does this HA technology or application affect an individual's autonomy?
4. How does this technology affect the accountability of the individual and of the military organisation?

Ethical aspects should be discussed prior to the start of HA research, as well as during development and deployment. Four important ethical aspects are identified in box 2.

Social aspects should be discussed during all phases of research, development and deployment. Social aspects should be discussed in the context of Defence strategy and recruitment of civilians into the armed forces, because of the relationship between society and the military, and because HA technology introduction may force subtle changes in attraction, recruiting and terms of service; with people in communications; and with civil society organisations, non-governmental organisations and other stakeholders in the public debate. Four important social aspects are identified (box 3).

Implementation and governance

Defence organisations have multiple decision-making procedures in place, whether for means and methods of warfare, medical, logistical or tactical decision making. It is anticipated that the organisational implementation of a HA-targeted ethics or ELSA framework will be best approached through existing structures, procedures and roles. A variety of stakeholders may be involved depending on the stage (research, development, technological maturation, deployment) and these may include legal and medical experts, HA subject matter experts, military operators, tactical commanders and communications or public affairs specialists. Above all, ELSA aspects should be considered by diverse stakeholders in a participatory and iterative process,[17] not in a one-off evaluation effort. Moreover, ongoing review at the strategic, organisational, tactical and individual level is advised when policy decisions have been made and HA is deployed.

CANDIDATE HA TECHNOLOGIES

Two candidate HA technologies are considered below, one with ancient roots but modern applications for Defence (pharmacological augmentation, a 'skin-in' intervention) and one emerging area (non-invasive brain stimulation (NIBS), 'skin-out').

Box 2 Ethical aspects

1. How does this human augmentation (HA) technology impinge on the human dignity of soldiers who employ it?
2. Are benefits and costs of this HA technology distributed fairly between Units and individuals?
3. How does this HA technology affect the agency of soldiers in their ability to act?
4. How does this technology affect the responsibility of military personnel, such as during operations?

Box 3 Social aspects

1. What is the human augmentation (HA) technology's impact on different societal levels (eg, spillover effects of HA technologies into a soldier's private life, social consequences when HA technology spills over to civilian use)?
2. To what extent can democratic institutions review and steer the development and deployment of HA technology?
3. To what extent is this technology aligned with values in society? Can this be improved?
4. Is there support from within society for the use of HA technology by military personnel?

Pharmacological augmentation

Pharmacology is a staple of society for treating conditions and a predominant feature of our healthcare model. Pharmacology is also 'the oldest trick in the book' when it comes to overcoming the normal limitations of human physiology (eg, hunger, pain or the need for sleep) and psychology (eg, fear, or survival instinct). These limitations are not weaknesses, but crucial signals related to self-preservation and homeostasis. There are ways to circumvent or suppress those signals; however, these do come at a cost. This cost is an essential decision-making element when gauging the risk-benefit balance of pharmacological means. This cost might be recoverable (eg, extended recovery after sustained operations which were enabled by drugs), or it might leave more permanent sequelae (eg, psychopathology after experiencing psychotropic medication).

There is a whole body of literature available on the historical evolution of 'shooting up', as one author puts it.[18] In this paper, we provide a short overview of current challenges and opportunities for military populations.

Mental versus physical enhancement

Physiology is by definition integrative, and the mental versus physical distinction is outdated, if only because of the profound psychological effects experienced with some physical capacity enhancing drugs, for example, xenon gas inhalation allowing for hypoxia tolerance at high altitude, or the psychological side effects of many active molecules, for example, 'roid rage', the overly antagonistic behaviour described in both human and animal models of chronic anabolic androgenic steroid use. We thus wish to emphasise there is no such thing as a solely physical performance enhancement drug. Altering one's sense of self, physical boundaries and thus self-regulation will always have larger implications than the intended effect.

Chronic versus acute use

A crucial distinction to make when discussing pharmacological means is whether these are applied with a long-term, chronic perspective or a short-term, acute perspective. Anabolic androgenic steroid prescription to increase muscle strength is an example of chronic use; punctual modafinil to alleviate the effects of acute sleep deprivation is an example of acute use. There is also a conceptual difference between providing an emergency solution to pain or sleep deprivation, should operational circumstances (and/or survival of the individual) require it and a long-term 'breeding' of abnormal capabilities in personnel due to chronic medication use. Usually (but not in all cases), this chronic versus acute distinction aligns with the distinction between permanent and temporary consequences. In general, acute punctual use will carry fewer risks for permanent consequences, and thus represent less of an ethical conundrum. Goodley[19] identifies three scenarios in which pharmacological interventions would be acceptable: (1) in 'life vs death' situations, (2) in cases of strategically exceptional mission requirement and (3) within restorative limits.

An element seldom taken into account is the between-individual variability in physiological responses[20] and the risk of addiction. As such, pharmacological means will rarely represent a 'one-size-fits-all' approach, unless one is willing to accept an attritional cost in the targeted population.

Evidence base and availability

The 20th century was tainted by several scandals revealing drug experimentation on both civilian and military personnel. Nazi experiments in extermination camps, and Soviet and American research programmes to identify 'mind control' drugs, all fostered long-lasting distrust in pharmacological experimentation, as well as a reluctance from military decision-makers to engage in pharmacological research. However, although Western militaries may have deprioritised pharmacological performance manipulations, drugs have taken centre stage again through their widespread use in criminal and terrorist organisations,[21] so much so that Captagon (a mixture of amphetamine and theophylline) was termed the 'Jihad Pill', both because of its widespread use, but mostly because of its trafficking funding these organisations (and the former Al-Assad regime in Syria).[22] Another drug, mephedrone (a combination of amphetamine and 3,4-methylenedioxymethamphetamine (MDMA, also known as ecstasy)), is making headlines in the Ukraine war under the name 'salt', causing both addictions and subtending criminality in those areas where a 'normal' economy no longer allows for survival.[23]

Furthermore, most Western nations have renounced their military pharmacological production capacities, which used to encompass all stages of the process, in favour of outsourcing to the commercial market. This choice may have resulted in cost-cutting in the short term, but, as the COVID-19 pandemic demonstrated quite dramatically, making national crisis management dependent on the laws of supply and demand in a free market economy is not without perils. Regarding performance enhancement, a simple example is the use of modafinil to counteract sleep deprivation (eg,[24]). Modafinil is a non-amphetaminic wake-promoting drug indicated to manage excessive daytime sleepiness in a range of conditions: narcolepsy, obstructive sleep apnoea, shift work disorder, Parkinson's disease and during prolonged military operations.[25] The usual dose is 100–200 mg two times per 24 hours. French research identified a co-drug, THN102 (a combination of modafinil and flecainide), which showed superior therapeutic effects on cognition preservation during 40 hours of extended wakefulness, with a safer profile regarding potential side effects.[25] Given the promising results, this compound was patented and Theranexus, a French biotech company spin-off of military research, bought the patent. However, since more promising compounds for clinical use, orexin receptor agonists, were soon identified (eg,[26]), the production of THN102 never actually started, making it commercially unavailable and legally unproducible by any other facility.

Chemical armoury: how (not) to use drugs

As identified by Van Cutsem and Pattyn,[27] the following recommendations should be considered with regards to pharmacological HA:

1. Physical weapons are controlled through an armoury and pharmacological 'weapons' should be controlled by the military medical chain of command regarding custody, transport and transfer.
2. Considering the between-individual variability in physiological responses, individual tolerance tests documenting all performance-related effects, as well as side effects, need to be scheduled to adequately inform cost-benefit decision making. This serves a double purpose: identifying who will reap benefits versus harm from use of a drug, and familiarising individuals with its effects. We do not send personnel into combat with weapons they have never used. The same should hold true regarding pharmacological means.
3. If pharmacological HA is implemented, monitoring and documenting effects during and after use should be mandatory, both to enhance the evidence base and to allow for fair compensation of individuals suffering damaging consequences, as for any occupational hazard.

Brain stimulation for human augmentation

Non-invasive brain stimulation (NIBS) is a promising non-pharmacological technique that may be effective for cognitive enhancement, involving modulation of neural activity through biophysical methods (eg, electrical current, magnetic fields, light, ultrasound) without the need for surgical intervention. NIBS has the potential to improve alertness and executive functioning, mood, stress and neuroplasticity.[28] For the military, these effects can be leveraged to boost operational effectiveness by increasing cognitive performance and countering unavoidable effects such as sleep deprivation.[28] Moreover, NIBS has the potential to contribute to military readiness, as an increase in neuroplasticity can support the acceleration and enhancement of learning and training.[29] A third application of NIBS is in supporting recovery in troops, particularly to support treatment of mental health issues. NIBS has the potential to augment cognitive functioning and may prove an attractive alternative to pharmaceutical interventions, as side-effects appear to be minimal.[28] An example of an attractive NIBS intervention is peripheral nerve stimulation, which has been shown to be effective in promoting wakefulness during sleep deprivation and accelerates and enhances learning of more complex tasks.[29 30]

NIBS is a promising method for human cognitive augmentation, with the potential to increase operational performance and military readiness, but some areas require further research to enable responsible and sustainable Defence applications. As with pharmacological interventions, side effects and individual variability should be carefully investigated. Although (side-) effects are mostly short-lived, monitoring these effects is key. NIBS may initially enhance aspects of cognitive functioning while decreasing performance of other mission-critical cognitive functions. It is also possible that an initial boost in cognitive functioning, such as attention, is associated with a decrease in cognitive functioning at a later time point, leading to the need for a longer recovery period and reducing military readiness.[28] Long-term effects of chronic use should also be investigated further, to ensure the well-being and long-term performance of military operators. Finally, it is important to note that NIBS for HA has the potential to support cognitive function, but should not be used to replace adequate sleep, nutrition, preparation and training when these are possible.

In summary, HA offers a number of benefits, opportunities and challenges to the Defence community, but HA research and operationalisation must take place within the boundaries of a nation's core values and beliefs, the rules-based international order and the freedoms that underpin their militaries' moral and ethical foundations.

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