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Neural Frontlines:
Exploring Future Battlefield amid Rise of Neurowarfare

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Abstract

Advancement in neurotechnologies has led policymakers to rethink the role of human cognition in modern warfare. As neuroscience unravels the intricate facets of the cognitive puzzle, human cognition has become the centerpiece of the technological revolution. The potential of these technologies to enhance, target, and weaponise the human brain places them at the heart of modern warfare. The United States Defense Advanced Research Projects Agency and China's Central Military Commission have poured sizable funds and resources into harnessing the untapped potential of these technologies for military purposes. This study examines the strategic and doctrinal implications of deploying neurotechnologies for military purposes. It highlights the challenges posed by neurowarfare, including legal ambiguities, ethical dilemmas, and moral concerns, which demand urgent attention. The study underscores the necessity of establishing robust regulatory frameworks to mitigate potential risks and unintended consequences associated with the militarisation of neurotechnologies.

Keywords: Cognitive Warfare, Neurotechnology, Neuroweapons, Brain Chips.

Introduction

In recent years, neurotechnologies have achieved significant breakthroughs, redirecting global technological focus toward a domain of unprecedented complexity and potential: the human brain. From treating causalgia during the American Civil War[1] to diagnosing shell shock in World War I and addressing Post-Traumatic Stress Disorder (PTSD) after the Vietnam War, neurotechnologies have evolved substantially since their inception in the 16th Century. Today, with technological advancements becoming the norm, neuroscientists are increasingly focused on deciphering and translating the brain's electrical activity. This is exemplified by Elon Musk's 'Neuralink', which successfully implanted a neural-invasive chip[2] capable of enabling humans to control external devices through thought, enhance cognitive abilities, and address various psychological conditions. Furthermore, these technologies hold the potential to erase traumatic memories and stimulate brain activity to improve cognitive functions, representing a transformative milestone in global technological advancement.

The United States (US) is leading advancements in neurotechnology by allocating substantial funds to Research and Development (R&D). Through agencies like the Defense Advanced Research Projects Agency (DARPA), the US has launched nearly 40 neuro-related initiatives, including the BRAIN Initiative and Next-Generation Non-Surgical Neurotechnology (N3). Militarily, these initiatives aim to enhance cognitive functions and execute complex

1 Francois Boller and Daniel Birnbaum, "Silas Weir Mitchell: Neurologists and Neurology during the American Civil War," in *War Neurology*, ed. L. Tatu and J. Bogousslavsky (Basel: Karger Publishers, 2016), 93-106.

2 Robert Hart, "Elon Musk's Neuralink Prepares to Implant Second Human Patient," *Forbes,* July 11, 2024, https://www.forbes.com/sites/roberthart/2024/07/11/elon-musks-neuralink-prepares-to-implant-second-human-patient/.

national security tasks such as controlling unmanned platforms, managing cyber-attacks, and enabling human-machine teaming. Similarly, China is heavily investing in neurotechnologies as part of its grand strategic ambition to emerge as a global leader by 2030. Initiatives like the development of New Concept Weapons (NCW) and cognitive operational concepts are integral to its broader goal of transforming the People's Liberation Army (PLA) into a world-class military by 2049.[3] These developments demonstrate a technological grail between two geopolitical competitors, each striving to avoid a critical lag in this pivotal domain.

Growing use of neurotechnologies for national security impetus also brings a minefield of ethical, legal, and privacy risks. The possible coupling of these technologies with external hardware and firmware poses the threat of information theft, improvisation, and data manipulation. Correspondingly, proliferation of neuroweapons including pharmaceuticals, Directed Energy Weapons (DEWs), microwave weapons, and laser beams could be used for cognitive sabotage, inhumane torture, and brutal interrogation. Beyond ethical dilemmas, ambiguity surrounding the current legal frameworks, particularly the Biological Weapons Convention (BWC), and the Geneva Convention, raises the issues of accountability and attribution.

The study argues that the militarisation of neurotechnologies will profoundly complicate the future battlefield landscape. The potential deployment of mind-disrupting weapons could enable precise targetting of decision-making centers, specifically the cognitive functions of military commanders and policymakers. This marks a paradigm shift in warfare, redirecting the focus to the cognitive domain—an area largely unexplored in earlier conflicts. Acknowledging the ethical and legal challenges inherent in these

[3] Caitlin Campbell, *China's Military: The People's Liberation Army (PLA)*, report (Washington, D.C.: Congressional Research Service, 2021), https://sgp.fas.org/crs/row/R46808.pdf.

technologies, the study underscores the urgent need for the international community to establish robust regulatory and governance frameworks to prevent the malicious use of neurotechnologies in military applications. While these technologies hold vast potential for civilian applications, this paper focuses specifically on their military dimensions.

The paper is divided into three sections. The first section discusses impacts of neurotechnologies on warfare by employing the conceptual framework of Revolution in Military Affairs (RMA). The second offers country-specific cases, specifically the US and China on their development and acquisition of neuroweapons. Meanwhile, the last section concludes the study by discussing legal and ethical challenges.

Methodology

The study is based on qualitative research methods. Data was collected from secondary resources involving books, journal articles, reports, dissertations, and archival records. Moreover, commentaries on media outlets, think tanks, and newspapers were incorporated to curate expert analysis on emerging trends in neurowarfare. Thematic analysis was employed to analyse the data drawn from secondary sources. To maintain credibility of the research, key themes were extracted and interpreted to uncover underlying trends in neurowarfare.

Theoretical Framework

Given the transformative potential of neuro weapons in reshaping tactical and operational dimensions of warfare, this study applies the concept of Revolution in Military Affairs (RMA) to analyse the complexities of the emerging domain of neurowarfare. RMA is broadly defined across a wide spectrum, generally referring to a paradigm shift in the nature and conduct of military operations. This shift renders obsolete or irrelevant one or more core

competencies of a dominant actor, introduces new core competencies in emerging dimensions of warfare, or achieves both simultaneously.'[4] However, analysts have also offered a more nuanced perspective by defining RMA as 'a major change in the nature of warfare brought about by the innovative application of technologies which, combined with dramatic changes in military doctrine and operational and organisational concepts, fundamentally alters the character and conduct of military operations.'[5] Typically, technological innovations are viewed as catalysts for RMA. However, technology alone is insufficient to achieve the transformative leap required for groundbreaking military advancements. Instead, it is the integration of novel operational concepts and the resulting re-organisation of military structures that fulfil the prerequisites for such progress.

There are three precursors for the complete realisation of RMA in any scenario— technological development, doctrinal innovation and organisational adaptation. During the First Gulf War, the success of *Operation Desert Storm* against Iraqi forces demonstrated that advanced high-tech weapon systems could serve as a decisive factor in future military operations.[6] Secondly, doctrinal innovation is essential for RMA, as it enables militaries to harness the potential of new weapons by formulating operational concepts that integrate these systems cohesively into established doctrinal frameworks. This is exemplified by the German *Wehrmacht's* innovative strategy during World War II, which concentrated artillery, armored, and mechanised infantry formations, supported by close airpower, to

4 Richard Hundley, *Past Revolutions, Future Transformations,* report (Santa Monica: RAND Corporation, 1999), 8, https://www.rand.org/pubs/monograph_reports/MR1029.html.

5 Benjamin S. Lambeth, "The Technology Revolution in Air Warfare," *Survival* 39, no.1 (1997):75.

6 Tsukamoto Katsuya, "The Gulf War as a Harbinger of a Revolution in Military Affairs," (paper presented at International Forum on War History, 2021).

penetrate enemy defences and achieve strategic surprise.[7] Lastly, a critical aspect of RMA is bureaucratic endorsement and institutional adaptation, involving changes to force structure and organisational reconfiguration to align with emerging technologies.[8]

The development of neuroweapons underscores the relevance of RMA by introducing a transformative dimension to modern warfare. Advancements in neurotechnologies, particularly cognitive weapons designed to manipulate or disorient enemy minds, have shifted war planners' focus toward the cognitive domain. These weapons reportedly possess the capability to disrupt or damage brain functions, as illustrated by the widely discussed case of Havana Syndrome. In this instance, hundreds of US officials from agencies such as the State Department, Department of Justice, and CIA, along with other diplomatic staff, were incapacitated during overseas assignments, allegedly due to exposure to non-kinetic weapons.[9] While the definitive source of these symptoms remains uncertain, experts suggest the involvement of neuroweapons intended to impair cognitive functions. This case highlights the operational precision and disruptive potential of neuroweapons, which could inflict severe losses on adversaries in crisis or conflict scenarios.

The development of neuroweapons has also demonstrated the doctrinal changes in the military strategies of great powers. China,

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7 Rolf Hobson, "Blitizkreig, the Revolution in Military Affairs and Defense Intellectuals," *Journal of Strategic Studies* 33, no. 4 (2011): 625-643.

8 Andrew F. Krepinevich, Jr, *The Origins of Victory: How Disruptive Military Innovation Undermines the Fates of Great Powers* (London: Yale University Press, 2023), 415.

9 Lewis Regenstein, "Havana Syndrome: The History Behind the Mystery," *Foreign Policy Research Institute,* April 1, 2024, https://www.fpri.org/article/2024/04/havana-syndrome-the-history-behind-the-mystery/.

a potential contender to the US hegemony has tried to seize the 'first mover' advantage by making necessary adjustments to its military strategic guideline for the new era. The recently published 'Cognitive Warfare Doctrine' has termed human cognition as a centerpiece of PLA's future military operations.[10] Reportedly, the PLA is developing cognitive degradation technologies to achieve an element of surprise against its adversaries in future conflicts.[11] On the other hand, the US has also undertaken neuroscientific research regarding human-machine teaming, hyper-enabled operators, and developing cyborg soldiers equipped with cognitive enhancement technologies enabling them to operate in austere battle conditions.[12] These technologies are also being systemised and integrated into the doctrinal patterns of both great powers which demonstrates their anticipation and responsiveness to the changing landscape of modern warfare.

However, the organisational and bureaucratic acceptance of these technologies by modern militaries is yet to be seen. Despite their purported lethality, neuroweapons have yet to be deployed in active combat, leaving their battlefield impact confined to theoretical speculation. Likewise, their unique characteristics and mode of employment require thorough scrutiny before getting them

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10 Nathan Beauchamp-Mustafaga, "Cognitive Domain Operations: The PLA's New Holistic Concept for Influence Operations," *Jamestown Foundation,* September 6, 2019, https://jamestown.org/program/cognitive-domain-operations-the-plas-new-holistic-concept-for-influence-operations/.

11 Yang Longxi, "Targeting Future Wars and Fighting the "Five Battles" of Cognition," *PLA Daily,* August 23, 2022, http://www.81.cn/jfjbmap/content/2022-08/23/content_322554.htm.

12 Yasim Tadjeh, "VSOFIC News: SOCOM Moving Forward with Hyper-Enabled Operator Concept," *National Defense Magazine,* May 5, 2020, https://www.nationaldefensemagazine.org/articles/2020/5/12/socom-moving-forward-with-hyper-enabled-operator-concept.

integrated into the existing operational frameworks. Furthermore, adapting force structures, implementing organisational transformations, and revising battlefield doctrines are inherently time-intensive processes, making the integration of these weapons into military culture a gradual endeavour. Consequently, the acceptance and assimilation of such technologies pose a substantial challenge for modern militaries.

Rethinking Neurotechnologies in Warfare: Applications and Implications

What once seemed confined to the realm of science fiction is rapidly becoming a reality. Technologies such as drones piloted through human thoughts[13] and neural implants erasing traumatic war memories are no longer mere concepts.[14] While these advancements offer promising applications, they also present profound security and ethical challenges. In 2012, scientists categorised neuroscience in warfare into two primary domains: performance enhancement and performance degradation.[15]

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13 Jason Dearen, "Drones Fly Controlled by Nothing More than People's Thoughts," *Independent,* April 22, 2016, https://www.independent.co.uk/news/science/drones-brain-thoughts-controlled-bci-braincomputer-interface-braincontrolled-interface-a6996781.html.

14 Cari Romm, "Changing Memories to Treat PTSD," *Atlantic,* August 27, 2014, https://www.theatlantic.com/health/archive/2014/08/changing-memories-to-treat-ptsd/379223/.

15 The Royal Society, *Brain Waves 3: Neuroscience, Conflict and Security,* report (London: The Royal Society, 2012), https://royalsociety.org/-/media/policy/projects/brain-waves/2012-02-06-bw3.pdf.

Performance Modulation: Enhancement and Degradation

Currently, three broad categories of neurotechnologies are employed in both military and civilian contexts to enhance cognitive abilities and address operational needs. These include:

1. Neuropharmacology
2. Neurostimulation
3. Brain Chip Interface (BCI)

Neuropharmacology

The use of drugs and amphetamines to enhance troop performance has a long history, tracing back to ancient times. Opium, hallucinogenic mushrooms, and coca leaves were reportedly consumed by ancient Greeks, Vikings, and Inca warriors to boost their combat effectiveness. During the World Wars, both Allied and Axis forces utilised performance-enhancing substances to endure the hardships of total war. Notably, the German Wehrmacht administered methamphetamine to its soldiers, helping them stay awake during prolonged missions. Among the Panzer crews, this substance became colloquially known as *Panzerschokolade* (tank chocolate), enabling soldiers to withstand harsh conditions and sustain operations for extended periods.[16] Similarly, the Royal Air Force employed Benzedrine and related stimulants to enhance the performance of airmen during prolonged periods of sleep deprivation. However, the Vietnam War, often referred to as the 'first pharmacological war,' witnessed large-scale distribution of neuromedicines. Between 1966 and 1969, approximately 225 million doses of stimulants, including codeine, Dexedrine, painkillers, and anabolic steroids, were supplied to US troops to maintain their operational effectiveness in challenging

[16] Peter Andreas, "How Methamphetamine Became a Key Part of Nazi Military Strategy," *Time,* January 7, 2020, https://time.com/5752114/nazi-military-drugs/.

combat conditions.[17] In addition to prescribed drugs, US soldiers during the Vietnam War also consumed illegal substances such as marijuana, hallucinogens, and heroin.[18] These illicit substances were often used alongside neuromedicines, reflecting the widespread reliance on both legal and illegal drugs during the conflict.

Currently, neuropharmacology focuses on developing groundbreaking drugs specifically designed to penetrate the blood-brain barrier with precision, enabling targetted interventions in brain functions and disorders.[19] Such medicines are envisioned to work in conjunction with neural implants, which would enable precise control over the release of drugs into specific areas of the brain. These advancements aim to regulate brain activity using microchips, allowing physicians to manage treatment procedures with unparalleled accuracy. Reflecting the growing interest in this field, the Pentagon has allocated USD 5.8 million under its Defense Health Program for FY 2024 to support the development of medicines targetting neurosensory injuries, psychological health, and resilience. These medicines are expected to offer remedies for a range of brain disorders, from mild to advanced, potentially fostering feelings of passion, satisfaction, and happiness among veterans. Notably, they hold the promise of erasing traumatic war flashbacks, providing effective treatment for PTSD, and addressing

17 Lukasz Kamienski, *Shooting Up: A History of Drugs in Warfare* (London: C Hurst and Company, 2017).

18 Lee N. Robins, *The Vietnam Drug User Returns,* report (Washington, D.C.: Special Action Office for Drug Abuse Prevention, 1974), https://prhome.defense.gov/Portals/52/Documents/RFM/Readiness/DDRP/docs/35%20Final%20Report.%20The%20Vietnam%20drug%20user%20returns.pdf

19 Michael Mitchell and Emily Han, "Bioengineers on the Brink of Breaching Blood-Brain Barrier," *Penn Today*, January 23, 2024, https://penntoday.upenn.edu/news/bioengineers-brink-breaching-blood-brain-barrier.

neurological conditions such as Parkinson's disease and dementia.[20]

Similar to neural enhancement, neuropharmaceuticals also present the potential for misuse, including the deliberate weakening or manipulation of adversary forces. This could involve inducing hallucinations, hypnosis, memory manipulation, or even fostering trust during interrogations by administering oxytocin to extract confessions.[21] Moreover, biological weapons such as genetically engineered bacteria, viruses, microbes, and fungi pose a severe threat by targetting the brain and central nervous system. These agents are capable of inflicting precise harm—ranging from injury and disability to death—while maintaining plausible deniability or achieving specific, tailored outcomes.[22]

Moreover, many of the neuromedicines lack credible medical research on the long-term health implications of these agents especially when used in austere battle conditions. Some of the potential downsides may be neural impairments or addiction, creating challenges for soldiers once they transition back into civilian lives. While some neuropharmaceuticals may enhance cognitive functions including memory and focus, they may also

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20 U.S. Department of Defense, *Fiscal Year (FY) 2024 President's Budget Operation and Maintenance Procurement Research, Development, Test and Evaluation,* report (U.S. Department of Defense, 2023), https://comptroller.defense.gov/Portals/45/Documents/defbudget/fy2024/budget_justification/pdfs/09_Defense_Health_Program/00-DHP_Vols_I_II_and_III_PB24.pdf.

21 Jason Koebler, "Oxytocin, the 'Trust Hormone,' Could Become New Interrogation Tool," *US News and World Report,* May 15, 2015, https://www.usnews.com/news/articles/2012/05/15/oxytocin-the-trust-hormone-could-become-new-interrogation-tool.

22 Armin Krishnan, *Military Neuroscience and the Coming Age of Neurowarfare* (London: Routledge, 2017), 106.

damage other cognitive functions including decision-making, judgment, and emotional control.[23]

Therefore, it is imperative for modern militaries to carefully adopt these technologies to ensure the mental and physical well-being of the combatants.

Neurostimulation

Neurostimulation is another type of performance enhancement that is capable of fluctuating the central nervous system's activity to improve mental functioning. Unlike neuro-optimisation, these technologies amplify individual or team performance beyond their threshold and allow the brain to process large amounts of information. Notable among them are transcranial direct current stimulation and transcranial magnetic stimulation. The former deals with emitting constant and low-frequency currents bombarded via electrodes on the head. While the latter utilises electromagnetic waves to generate a potent electrical field to stimulate nerve cells in the brain.[24] These two technologies are believed to target medial brain regions responsible for cognitive functions including the insula, medial prefrontal cortex, and anterior cingulate cortex to alter cortical activity which modulates the combatant's decision-making process and regulates emotional condition under stressors.

With the help of neurostimulation, military commanders may be able to stimulate cognitive functions of their troops, enhance decision-making, and suppress emotions under frantic stress. From infantry soldiers to pilots, neurostimulation appears as a promising agent to boost cognitive functioning and battlefield

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23 Armin Krishnan, "Attack on the Brain: Neurowars and Neurowarfare," *Space and Defense* 9, no. 4 (2016): 16.

24 James Giordano, *Neurotechnology in National Security and Defense: Practical Considerations, Neuroethical Concerns* (New York: CRC Press, 2015), 171-172.

aptitude. Even if tailored more specifically, this technology can bolster command and control (C2) by maximising efficiency through improved decision-making in a complex landscape.[25]

Nonetheless, neurostimulation faces its own set of challenges, particularly with the existence of sonic and ultrasonic weapons. Devices such as sound cannons, noise bazookas, hailing devices, and sonic bullets are examples of performance degradation techniques. These weapons are designed to project high-pitched audible waves over long distances, potentially disrupting cognitive functions and impairing performance in targetted individuals. Likewise, radio frequency (RF) weapons including tasers, laser guns, microwave weapons, and particle beams deploy intense energy to cause damage and destruction to human and physical infrastructure.[26]

Moreover, the incompatibility of neurostimulation technologies with established military culture may discourage generals and field commanders from adopting these advancements for combat formations. Similarly, concerns related to accountability, monitoring, health, and safety pose significant barriers to the integration of neurotechnologies into doctrinal and strategic frameworks. Ethical challenges surrounding informed consent and individual autonomy further complicate the deployment of neurostimulation techniques by modern militaries, raising questions about their practicality and acceptance within operational contexts.

Brain Chip Interfaces (BCI)

BCI is an emerging and potentially disruptive domain of technology that enables man-machine neural communication. It refers to a system that measures and traces the activity of the central nervous

25 Krishnan, "Attack on the Brain": 7.

26 Krishnan, *Military Neuroscience and the Coming Age of Neurowarfare,* 117.

system and generates synthetic output that augments functioning of the nervous system and improves its interaction with the external and internal environment.[27] In other words, the BCI enables a human to interact with external gadgets using his/her thoughts. As a great leap forward in neurotechnological research, BCI aims to make human brains immune from corporeal margins and allow humans seamless interaction with machines.

Although initially developed for civilian applications, military planners are increasingly considering the adoption of these minute neural chips to achieve cognitive superiority on future battlefields. The U.S. Defense Advanced Research Projects Agency (DARPA)[28] and China's Military Brain Project[29] are actively researching brain-computer interfaces (BCI) for a range of applications. These include human-machine teaming supported by cloud infrastructure, development of advanced cybernetic organisms (cyborgs), and assisting soldiers in erasing traumatic memories as they reintegrate into civilian life.

Similar to its potential for cognitive enhancement, BCIs could also emerge as one of the most dangerous mechanisms for performance degradation by manipulating the information stored or transmitted by the user's brain, reprogramming invasive implants, and interfering with the neural functions of individuals

27 Brooke Becher, "Brain Computer Interfaces, Explained," *Built In,* July 24, 2024, https://builtin.com/hardware/brain-computer-interface-bci.

28 Defense Advanced Research Projects Agency, "N3: Next Generation Nonsurgical Neurotechnology," *Defense Advanced Research Projects Agency*, https://www.darpa.mil/research/programs/next-generation-nonsurgical-neurotechnology.

29 Mu-Ming Poo et al., "China Brain Project: Basic Neuroscience, Brain Diseases, and Brain-Inspired Computing," *Neuron* 92, no. 3 (2016): 591-96.

equipped with such enhancements.[30] As the adoption of invasive BCIs approaches mainstream use, these systems would also become an enticing target for exploitation by hackers and even tech corporations, raising serious concerns about security, privacy, and ethical misuse.[31] The possible bonding of the BCI with the Apples and IOs might allow the hackers to inflict damage on the neutrally implanted people.

Great Power Competition in Neurotechnologies

The contemporary security landscape is dominated by Sino-US great power rivalry. The ongoing Ukraine war and hovering concerns of the 'fourth Taiwan Strait crisis' are signaling a shift in geopolitical tectonics. To maintain dominance on the global geopolitical landscape, both states are utilising political, economic, and military means to achieve a competitive overmatch. Against this backdrop, neuroweapons can be juxtaposed with other military means to achieve a cutting-edge ascendancy over adversaries. The following section discusses the efforts of the US and China in utilising neurotechnologies for military purposes.

United States and Neurocompetition

The US government has prioritised neurotechnologies as a national security interest to maintain a competitive edge over its adversaries. In 2013, former President Barack Obama launched an ambitious initiative titled *Brain Research Through Advancing Innovative Neurotechnologies (BRAIN)*, aimed at addressing neurological and communication disorders, improving cognitive

30 Urpi Armengol et al., "Brain-Hack: Remotely Injecting False Brain-Waves with RF to Take Control of a Brain-Computer Interface," (Proceedings of the 5th Workshop on CPS&IoT Security and Privacy, 2023).

31 Shaza Arif, "Neuralink Implant: Scrolling via Thoughts," *Centre for Aerospace & Security Studies,* April 4, 2024, https://casstt.com/neuralink-implant-scrolling-via-thoughts/.

health, and advancing the understanding of brain functions. Overseen by the National Institutes of Health (NIH), the initiative initially received USD 100 million in federal funding, supplemented by USD 200 million in private investments.[32] To date, the NIH has awarded approximately 1,469 research grants to support various brain-related studies.[33] For the current fiscal year, the US government has allocated USD 402 million to the BRAIN initiative, underscoring its continued commitment to advancing neuroscience research and innovation.[34] In addition to the NIH, several public organisations have partnered in the BRAIN initiative, including the National Science Foundation (NSF), DARPA, the military services, the Intelligence Advanced Research Projects Activity (IARPA), and the Food and Drug Administration (FDA).

The likelihood of civilian-developed technologies permeating military applications is significant, with DARPA playing a pivotal role as a mentor to the U.S. Department of Defense as discussed further.

DARPA's Role in Military Neuroscientific Research

In the realm of military neuroscientific research, DARPA plays a leading role in advancing innovative solutions for the US military.

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32 Tim Requarth, "This is Your Brain. This is Your Brain as a Weapon," *Foreign Policy,* September 14, 2015, https://foreignpolicy.com/2015/09/14/this-is-your-brain-this-is-your-brain-as-a-weapon-darpa-dual-use-neuroscience/.

33 BRAIN Initiative, "Funded Awards," *BRAIN Initiative*, Accessed September 18, 2024, https://braininitiative.nih.gov/funding/funded-awards?page=0.

34 BRAIN Initiative, "Understanding BRAIN Initiative Budget," *BRAIN Initiative*, Accessed September 18, 2024, https://braininitiative.nih.gov/funding/understanding-brain-initiative-budget.

With an annual budget of USD 4.122 billion,[35] the agency is engaged in multiple initiatives focused on biotechnology, brain amplification, and human-machine interfaces. Neurotechnologies, in particular, have been prioritised due to their potential utility in shaping future combat scenarios.

DARPA has a longstanding history of advancing neurotechnologies for military applications. In 1974, it launched the *Closed Coupled Man Program*, leveraging electroencephalography to explore direct communication between humans and machines by monitoring neural states such as fatigue, panic, and decision-making.[36] By 2003, DARPA initiated a strategic plan to translate human thoughts into actionable outcomes, laying the foundation for modern human-machine teaming.

This vision continued with the 2012 Cognitive Technology Threat Warning System (CT2WS)—a soldier-portable device integrating AI, cameras, and brain signals to reduce cognitive burdens and enhance threat detection.[37] These developments indicate US preparation for future conflicts where humans and machines may be able to think seamlessly through cortically attached AI systems, brain-to-brain communication, and direct information processing through the brain. In other words, it will transform the existing

35 Defense Advanced Research Projects Agency, "Budgets and Finance," *Defense Advanced Research Projects Agency*, Accessed September 20, 2024, https://www.darpa.mil/about-us/budget-and-finance#:~:text=The%20President's%20FY2025%20budget%20request,Congressional%20testimony%20by%20DARPA%20leadership.

36 Robbin A. Miranda et al., "DARPA-Funded Efforts in the Development of Novel Brain-Computer Interface Technologies," *Journal of Neuroscience Methods* 244 (2015): 52-67.

37 Bruce Sterling, "Augmented Reality: DARPA Cognitive Technology Threat Warning System," *Wired,* September 19, 2012, https://www.wired.com/2012/09/augmented-reality-darpa-cognitive-technology-threat-warning-system/.

Observe, Orient, Decide, Act (OODA) loops of the US military through human-machine teaming.

In recent years, DARPA has shifted focus to non-invasive solutions. The *Next-Generation Nonsurgical Neurotechnology (N3)* programme aims to develop high-performance, bi-directional brain-machine interfaces (BMIs) that do not require surgical intervention. These interfaces are intended to enable complex tasks such as controlling unmanned systems, active cyber defence, and advanced human-machine teaming during intricate military missions. The N3 explores both completely noninvasive interfaces, which are entirely external to the body, and minimally invasive systems that involve nanotransducers temporarily and nonsurgically delivered to the brain to enhance signal resolution. These approaches utilise modalities such as optics, acoustics, and electromagnetics to record neural activity and transmit signals back to the brain with high speed and precision. By removing the need for surgery, N3 systems seek to expand the pool of individuals who can benefit from neural interface technologies, including able-bodied service members and clinical populations requiring treatments like deep brain stimulation for neurological conditions.[38] Meanwhile, *Project ElectRX*, backed by USD 78 million, employs light, sound, and magnetic waves to address PTSD and chronic pain in post-conflict scenarios.[39]

These initiatives highlight DARPA's role in revolutionising future warfare, particularly through seamless integration of human cognition and machine intelligence to enhance decision-making

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38 Eliza Strickland, "DARPA Wants Brain Interfaces for Able-Bodied Warfighters," *IEEE Spectrum,* September 10, 2018, https://spectrum.ieee.org/darpa-wants-brain-interfaces-for-able-bodied-warfighters.

39 Shaheer Ahmad, "Shifting Dynamics: Brain Chips as the Next Battlefield," *Centre for Aerospace & Security Studies,* August 15, 2024, https://casstt.com/shifting-dynamics-brain-chips-as-the-next-battlefield/.

and combat capabilities. Once fully developed, DARPA's initiatives in BMIs and neurotechnologies are poised to transform the nature of warfare by seamlessly integrating human cognition with external systems. This advancement could lead to the widespread deployment of remote-controlled platforms, significantly reducing human exposure to combat risks. Neural implants also have the potential to enhance the cognitive capabilities of future soldiers, enabling accelerated decision-making, integration with memory-enhancing systems, and access to vast informational resources through thought alone.

Such innovations will necessitate a fundamental shift in military strategies, doctrinal frameworks, and tactical planning to accommodate these enhanced capabilities. As DARPA continues to achieve breakthroughs in neuroscience and neurotechnology, the implications for future warfare will compel military planners and policymakers to reassess the utility, ethics, and operational integration of these technologies in shaping combat scenarios and strategic objectives.

Miscellaneous Private Sector Actors

Besides DARPA, the US military is also working on several other projects to enhance cognitive warfare capabilities. The U.S. Special Operations Command (USSOCOM) is working on a Hyper-enabled Operator (HEO), a tactical AI assistant which utilises sensors, communications, and human-machine interface to augment troops' performance in the saturated war zones.[40] Similarly, the US Army Combat Capabilities Development Command (DEVCOM) envisions the future 'super soldiers' marching on the battlefield furnished with visual and neural enhancement equipment to bolster

[40] Shannon Houck et al., "Changing Hearts and Brains: SOF Must Prepare Now for Neurowarfare," *Small War Journals,* December 12, 2021, https://smallwarsjournal.com/jrnl/art/changing-hearts-and-brains-sof-must-prepare-now-neurowarfare.

operational capability.[41] These efforts demonstrate US interest in developing and integrating neurotechnologies to enhance situational awareness, minimise casualties, and improve operational efficiency in future battles.

China's Advancement in Neurotechnologies for Strategic Dominance

China, positioned as a potential challenger to US hegemony, is strategically positioning itself to achieve dominance on the global geopolitical stage. Beyond its objectives of reclaiming disputed territories and maintaining a favourable regional balance of power, China's grand strategy is about technological advancement. With a stated goal of becoming a global leader in innovation by 2030, this strategy underscores its commitment to leveraging cutting-edge developments to enhance its geopolitical influence and military capabilities.[42] The domain of neurotechnologies, with its rapidly evolving advancements, has also become a focal point of China's strategic investments, driven by the imperative to maintain technological parity and avoid falling behind the US.

In 2016, China initiated its national brain project, mirroring the US BRAIN initiative, to explore the complexities of the human brain and advance its understanding of neurotechnologies. To date, the project has received USD 746 million in funding, reflecting China's commitment to keeping pace with its American counterparts.[43] In

41 Peter Emanuel et al., *Cyborg Soldier 2050: Human/Machine Fusion and the Implications for the Future of the DOD,* report (Washington, D.C.: US Army DEVCOM Chemical Biological Center, 2019), https://apps.dtic.mil/sti/pdfs/AD1083010.pdf.

42 Pablo Robels, "China Plans to be a World Leader in Artificial Intelligence by 2030," *South China Morning Post,* October 1, 2018, https://multimedia.scmp.com/news/china/article/2166148/china-2025-artificial-intelligence/index.html.

43 Dennis Normile, "China Bets Big On Brain Research with Massive Cash Infusion and Openness to Monkey Studies," *Science Insider,*

parallel, the Central Military Commission, which oversees China's military affairs, has launched a dedicated military brain project to evaluate and develop applications of neuroscience for defence purposes. This initiative aligns with President Xi Jinping's broader military modernisation agenda, aimed at transforming the People's Liberation Army (PLA) into a 'world-class' military force by 2049.[44] By integrating advancements in neurotechnologies, China seeks to enhance its military capabilities and secure a competitive edge in future conflicts.

Cognitive Warfare in China's Military Strategy

Since the era of Mao Zedong, China's military strategy has continuously evolved to align with shifting battlefield dynamics. Transitioning from the concept of the 'people's war' to modern information warfare, the PLA has now adopted a strategy centred on 'intelligentized wars.' [45] This strategy integrates several key elements, including advanced information processing, accelerated decision-making enabled by cloud control and Artificial Intelligence (AI), and the synergy of AI, cybersecurity, and unmanned systems to execute swarm offensives against adversaries in future conflicts.

Cognitive warfare, incorporating the use of neurotechnologies, is a critical component of this approach, extending the battlefield from traditional domains such as air, sea, land, and space into the cognitive domain. This shift underscores China's focus on cutting-

September 20, 2022, https://www.science.org/content/article/china-bets-big-brain-research-massive-cash-infusion-and-openness-monkey-studies.

44 M. Taylor Fravel, "China's "World-Class Military" Ambitions: Origins and Implications," *The Washington Quarterly* 43, no. 1 (2020): 85-99.

45 Yatsuzuka Masaaki, "PLA's Intelligentized Warfare: The Politics on China's Military Strategy," *Security and Strategy* 2, (2022): 17-36.

edge technologies to gain an advantage in both conventional and unconventional military operations.

Chinese military strategists believe that human cognition lies at the centre of 'intelligentized war' and that strategic objectives may be achieved by directly manipulating human cognition.[46] It has been argued that the cognitive domain will be the ultimate domain of great power competition[47] and tampering with the enemy's mind or subconsciously controlling it will induce panic and hallucinations, forcing surrender.[48] According to General Qi Jianguo, former Chief of Staff of the PLA, nations that achieve dominance in next-generation AI capabilities will hold the key to securing national salvation by controlling the critical domain of human cognition.[49]

China has developed a structured cognitive warfare doctrine that integrates various technologies and capabilities, broadly categorised into *Cognition* and *Subliminal Cognition*.

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46 Li Dapeng, "How to Fight Intelligent Warfare," *China Youth Daily Group,* July 11, 2019, https://zqb.cyol.com/html/2019-07/11/nw.D110000zgqnb_20190711_3-12.htm.

47 Guo Yunfei, "Fighting for Brain Control, How Can We Win The Future War Without Fighting?," *China Military Network-People's Liberation Army Daily,* June 2, 2020, http://www.81.cn/xxqj_207719/xxjt/ll/9826822.html.

48 Zhu Xueling Zeng Huafeng "Brain Control Warfare: A New Model of Future War Competition," *PLA Daily*, October 18, 2017, https://www.sohu.com/a/198597081_778557.

49 Qi Jianguo, "Seize the Commanding Heights of Artificial Intelligence Technology Development," *China Military Network Ministry of National Defense Network,* July 25, 2019, http://www.81.cn/jfjbmap/content/2019-07/25/content_239260.htm.

Cognition encompasses technologies such as:

- Cognitive surveys,
- Cognitive interference, and
- Cognitive strengthening.[50]

Cognitive survey technology specifically focuses on collecting and analysing brain signals, enabling the extraction of neural data to better understand and potentially influence cognitive processes.[51] Theoretically, if the physiological signals are quantified, they will likely consolidate external and internal brain control. Similarly, it is also crucial for human-machine teaming in war settings, allowing warfighters to directly access and exercise seamless control over sophisticated weaponry.

Cognitive interference technology is potentially disruptive. It includes tools which are intended to inflict harm or damage to the human brain through a certain distance. This technology could be used against adversary's political officials, theatre commanders, and tactical groups operating on the ground. Meanwhile, *cognitive strengthening technology* is aimed at enhancing mood, bolstering resilience under stressors, and enabling soldiers to fight in austere conditions.[52]

Subliminal Cognition capabilities include integration of technologies and methodologies that are applied comprehensively to paralyse the adversary's C2. To create a cognitive fog of war, it employs the use of propaganda, deep fakes, and disinformation

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50 Zhang Guangsheng, Li Yongli and Wang Haoxian, "A Brief Analysis of the Basic Essence of Cognitive Domain Warfare," *PLA Daily,* September 8, 2022, http://www.81.cn/jfjbmap/content/2022-09/08/content_323692.htm.

51 Guangsheng et al., "A Brief Analysis of the Basic Essence of Cognitive Domain Warfare."

52 Guangsheng et al., "A Brief Analysis of the Basic Essence of Cognitive Domain Warfare."

campaigns to create a favourable environment and delay international response due to the shrouded ambiguity. These tactics are likely combined with PLA's *Neurostrike* Programme.[53]

Pursuit of Neuroweapons

To gain a strategic advantage in cognitive warfare, China has announced the development of neurological weapons and established operational concepts to maximise their battlefield utility. Referred to as *New Concept Weapons (NCWs)*, these include DEWs, information-based weapons, and biological and chemical weapons, designed to achieve cognitive superiority against adversaries, particularly the US.[54] Among these, DEWs are reportedly intended to 'disorient enemy minds' and diminish their will to fight. Reports from sources suggest that China is also exploring mind-controlling weapons capable of influencing human cognition during conflicts.[55] The PLA's gradual shift toward cognitive warfare underscores the significance of NCWs in its evolving military strategy. The development of new operational frameworks, such as *Cognitive Domain Operations*, is likely to integrate NCWs into active combat scenarios.[56] These

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53 Ryan Clarke, Xiaxou Sean Lin and LJ Eads, *"Enumerating, Targeting and Collapsing the Chinese Communist Party's Neurostrike Program, Aggregating Intelligence Fragments and the Power of Network Graphs,* report (Washington, D.C.: CCP BioThreats Initiative), Accessed 30 October 2024, https://shorturl.at/tDe6t.

54 Marcus Clay, "New Concept Weapons: China Explores New Mechanisms to Win War," *Jamestown Foundation,* April 23, 2021, https://jamestown.org/program/new-concept-weapons-china-explores-new-mechanisms-to-win-war/.

55 Bill Gertz, "Chinese Brain Warfare includes Sleep Weapons, Thought Control," *Washington Times,* December 20, 2023, https://www.washingtontimes.com/news/2023/dec/20/inside-ring-chinese-brain-warfare-includes-sleep-w/.

56 Beauchamp-Mustafaga, "Cognitive Domain Operations: The PLA's New Holistic Concept for Influence Operations."

advancements are expected to play a pivotal role in the PLA's grey zone operations and ongoing disputes in the South China Sea.

Reports suggest that China's neurostrike capabilities extend beyond traditional neuroweapons, encompassing the advanced use of human-machine interfaces to exert control over large populations and suppress dissent to preempt resistance. These reports indicate that neuroweapons are being integrated into China's standard arsenal, signalling ambitions to deploy these technologies in regular combat scenarios. This integration could enable precision strikes against adversaries during crises, reflecting a strategic focus on utilising neuroweapons for both domestic stability and international operations.[57] The development of these weapons and their associated operational concepts aligns with China's strategic anticipation of threats in key areas, including the First Island Chain, the South China Sea, and Xinjiang. These advancements highlight the dual-use potential of neuroweapons to address both internal and external security challenges, reinforcing China's broader geopolitical and military objectives.

Despite claims of China's development of New Concept Weapons (NCWs), assessing the veracity of neuroweapons use in crisis or conflict scenarios remains challenging. However, notable incidents in 2017 and 2018 in Guangzhou have drawn attention to the potential deployment of such technologies.

In late 2017, a U.S. Commerce Department employee reported waking to a distinct chirping sound emanating from a specific location, which triggered intense pressure in her head. Over the following months, she endured varying degrees of head sensations and was subsequently evacuated to the US in 2018. There, she

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57 Ryan Clarke, Xiaoxu Sean Lin and Lj eads, *Enumerating, Targeting and Collapsing the Chinese Communist Party's NeuroStrike Program,* report (CCP Biothreat Initiative, 2020), https://www.ccpbiothreats.com/initiatives/project-one-ephnc-23hjt-xkgdj.

continued to experience lingering effects, including visual impairment, coordination issues, and memory loss. In the same year, similar symptoms prompted the evacuation of over a dozen US consulate members from China.[58]

During the 2020 standoff between China and India at the Line of Actual Control (LAC), Jin Canrong, Deputy Dean of the School of International Relations at Renmin University, Beijing, alleged that the Chinese PLA used non-lethal microwave weapons to disorient Indian troops and retake a strategic hilltop. Canrong claimed the weapon caused vomiting among Indian soldiers, forcing them to retreat.[59] India denied the claim, labeling it as fake news.[60] However, an annual review by India's Ministry of Defence mentioned the use of an 'unorthodox weapon' during the conflict, lending some plausibility to the allegation.[61]

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58 Josh Lederman, "Evacuated after 'Health Attacks' in Cuba and China, Diplomats Face New Ordeals in U.S.," *NBC News,* October 29, 2018, https://www.nbcnews.com/news/investigations/evacuated-after-health-attacks-cuba-china-diplomats-face-new-ordeals-n920241.

59 Aakriti Sharma, "Has India Finally Acknowledged That Chinese PLA Used Microwave Weapons Against Indian Soldiers in Ladakh?," *Eurasian Times,* January 6, 2021, https://www.eurasiantimes.com/has-india-finally-acknowledged-that-chinese-pla-used-microwave-weapons-against-indian-soldiers-in-ladakh/.

60 David Hambling, "India Disputes Claim That China Routed Their Troops With Microwave Blaster," *Forbes,* July 19, 2021, https://www.forbes.com/sites/davidhambling/2020/11/20/disputed-claim-that-china-routed-indian-troops-with-microwave-blaster/.

61 Government of India, "Year End Review – 2020 Ministry of Defence," January 1, 2021, https://pib.gov.in/Pressreleaseshare.aspx?PRID=1685437.

Given the agreement between the two states to avoid firearms or explosives in disputed areas,[62] non-lethal weapons like microwave systems remain a plausible option. Such events, even if disputed, highlight concerns over the use of unconventional weapons in conflicts and their potential to serve as advanced psychological tools to disrupt and demoralise adversaries.

These instances demonstrate China's ability to deploy its NCWs with modern operational concepts making it an influential player in the emerging landscape of neurowarfare. Since the Gulf War, the Chinese PLA has been studying the US military's doctrinal evolution and way of war. The newly adopted 'intellegentised warfare' shows the PLA's anticipation of the advantages of neuroweapons, and development of new operational concepts to operationally deploy them to achieve cognitive overmatch over its regional and global adversaries.

Challenges of Integrating Neurotechnologies in Warfare

The growing adoption of neurotechnologies in future warfare presents considerable challenges, particularly in the legal, ethical, and moral domains. Some of these critical issues are outlined below:

Legal Challenges

The throttle of human-machine integration presents many challenges, particularly in keeping pace with existing legal frameworks. While international agreements such as the *Chemical Weapons Convention (CWC)* and the *Biological Weapons Convention (BWC)* prohibit the development of neurobiological weapons, modern neuroweapons—such as acoustic, microwave, and

62 United Nations, "Agreement between India and China on Confidence-Building Measures in the Military Field along the Line of Actual Control in the India-China Border Areas," November 29, 1996, https://peacemaker.un.org/en/node/9227.

electromagnetic systems—fall outside the scope of these definitions. This legal ambiguity creates a 'grey zone,' enabling such technologies to evade current regulatory frameworks. Moreover, the dual-use nature of neurotechnologies, where they serve both civilian and military purposes, heightens the risk of their weaponisation. This duality complicates efforts to regulate or explicitly ban malicious use of these technologies under the existing conventions, further challenging global disarmament and non-proliferation efforts.

The CWC also defines toxic chemicals as 'any chemical which, through its chemical action on life processes, can cause death, temporary incapacitation, or permanent harm to humans or animals.'[63] However, modern neuroweapons frequently employ unconventional agents that challenge traditional biolegal and arms control frameworks. For instance, some neuroweapons, such as microwave-based systems, can alter neural functions without causing direct physical damage to the brain. These technologies often utilise agents with low or negligible toxicity, operating in microdoses that fall outside conventional definitions of toxic chemicals as outlined by the CWC. This ambiguity enables such neuroweapons to bypass current regulatory frameworks, further complicating efforts to address their development and use within existing legal structures.

63 Organisation for the Prohibition of Chemical Weapons, "Article II, Definitions and Criteria, Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on Their Destruction," *Organisation for the Prohibition of Chemical Weapons*, June 7, 2020, https://www.opcw.org/chemical-weapons-convention/articles/article-ii-definitions-and-criteria#:~:text=%E2%80%9CToxic%20Chemical%E2%80%9D%20means%3A,harm%20to%20humans%20or%20animals.

Issue of Informed Consent

Apart from conventional medical experiments carried out on ill people, neuroweapons are tested in classified settings with the possibility of targetting healthy individuals resulting in partial or permanent brain damage. Furthermore, national security institutions often test the utility of these agents on individuals who may be unaware that they are being used as test subjects.[64] Such practices frequently bypass internal ethics reviews,[65] raising profound ethical and moral concerns. In these instances, individuals subjected to classified projects are typically unable to seek legal recourse against the government, as the state can invoke 'state secrets' privileges to shield its actions from judicial scrutiny.

Neurocrimes

Non-state actors, criminals, and hostile intelligence agencies might use neuroweapons for nefarious designs including torture, manipulation, and forced confessions from innocent individuals. Punitive torture is an illustration of this phenomenon where neurotransmitters are used to manipulate the time perceptions of a prisoner. It has been argued that this technique is a cost-effective method of caging a convict by giving him a drug and placing him in prison for a few days, which in turn would make him perceive incarceration for years.[66] Notwithstanding the rationale of such

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64 Margaret Winter, "Don't Let the Military's Deadly "Pain Ray" Machine Invade the L.A. Jail," *ACLU,* August 26, 2010, https://www.aclu.org/news/national-security/dont-let-militarys-deadly-pain-ray-machine-invade-la-county-jail.

65 Central Intelligence Agency, "MK-Ultra/Mind Control Experiments," *Central Intelligence Agency*, December 23, 1984, https://www.cia.gov/readingroom/docs/CIA-RDP88-01070R000301530003-5.pdf.

66 Dylan Love, "Future Mind-Altering Drugs Could Make Prisoners Think They're in Jail for 1,000 Years," *Business Insider India,* August 19, 2014, https://www.businessinsider.in/future-mind-altering-drugs-

techniques, it can allow governments to conceal the torture due to the absence of physical evidence.

Overdose of Neuromedicines

Psychiatric drugs are considered mood stabilisers, anti-depressants, and antipsychotics to modulate brain functions. However, these agents are often overprescribed and misused for performance enhancement. These drugs can provide relief and enhance cognitive functions but with a burgeoning cost. In the future, military commanders may have the capability to modulate the neural activity of their troops, raising regulatory concerns over the potential misuse or overdose of neuromedicine.[67] This scenario underscores the need for robust oversight mechanisms to address the ethical, health, and operational risks associated with such practices.

Mind Hacking

As neurotechnologies modernise, mind hacking becomes a pertinent concern for strategic and military planners. The possible co-option of neural implants with external devices aggrandises the risk of information theft, hacking, and reprogramming of neutrally enhanced soldiers. Similarly, adversary forces can inflict brain damage on future 'super soldiers' by targetting them through mind-damaging weapons including lasers, microwaves, and DEWs.[68]

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could-make-prisoners-think-theyre-in-jail-for-1000-years/articleshow/40425325.cms.

67 Heloise Goodley, "Pharmacological Performance Enhancement and the Military," (paper, Chatham House, 2020), https://www.chathamhouse.org/sites/default/files/2020-11/2020-11-11-pharma-enhancement-military-goodley_0.pdf.

68 Darlene Storm, "Hacking the Mind: 3 New Brain Hacks Expose New Realms of Security and Privacy Risks," *Computer World,* August 27, 2012, https://www.computerworld.com/article/1372372/hacking-the-mind-3-new-brain-hacks-expose-new-realm-of-security-privacy-risks.html.

Besides this, the emergence of DNA hacking could enable states and non-state actors to inject viruses into the human brain, opening a plethora of new problems.[69]

Neueroweapons and Future Warfare: What Comes Next?

Just as early warnings[70] about the potential dangers of cyberwarfare highlighted its transformative impact, this paper aims to draw attention to the emerging threat of neurowarfare, specifically its focus on mind control and direct manipulation. National security communities and military organisations must remain vigilant regarding advancements in neuroscience and their implications for defence. While significant progress is being made in developing performance-enhancement technologies, equal attention must be given to monitoring potential risks associated with performance degradation and implementing necessary countermeasures.

Advancements in neuroscience are expected to play a pivotal role in shaping great power rivalries, with the US and China actively pursuing neural and ocular enhancement technologies for their soldiers. These enhancements aim to improve alertness and enable stealthy communication through methods such as telepathy. Such capabilities are designed to empower troops to execute complex operations, including neutralising command-and-control systems, disabling radars, destroying fuel and ammunition depots, or rendering nuclear missiles, delivery vehicles, and launch systems inoperative.

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69 "Crocus-Moscow Tells About Chips in Head of Terrorists," *RBC Ukraine*, April 1, 2024, https://newsukraine.rbc.ua/news/crocus-moscow-tells-about-chips-in-heads-1711935747.html.

70 John Arquilla and David Ronfeldt, "Cyberwar is Coming," *in In Athena's Camp: Preparing for Conflict in Information Age*, ed. John Arquilla and David Ronfeldt (Santa Monica: RAND Corporation, 1997), 23-61.

In addition, neuroweapons provide a unique toolkit that could inflict psychological and physical harm on the adversary's morale. Due to enhanced precision, these weapons could be employed to target key military planners, strategists, theatre commanders, and government officials, to inflict 'neural shock and awe.' Such actions will adversely impact interstate relations and aggravate mistrust and uncertainty.

Similarly, future conflicts are likely to see an increased reliance on Special Forces operating covertly behind enemy lines to carry out sabotage missions. In such scenarios, BCIs and other neural enhancement technologies could enable Special Forces personnel to endure extended operations, counteract sleep deprivation, and manage battlefield stress effectively. This potential is underscored by reports of cognitively enhanced fighters encountered by Western forces in Syria, who used amphetamines such as *Captagon* to remain awake for extended periods and engage in combat with reckless ferocity.[71] These examples highlight the operational advantages and ethical dilemmas associated with cognitive enhancement technologies in modern warfare.

Considering the lethality of these technologies in war, the international community must regulate them to prevent misuse. In this regard, existing legal frameworks and conventions should be revised, or new legal frameworks developed focused on regulating neurotechnologies in the military context. Instead of banning military-related research, CWC's definition of toxic chemicals should include the non-lethal chemical agents responsible for neural impairments and cognitive degradation. Likewise, states

71 U.S. Central Command, "$1.4 Million Terrorist Drug Cache Seized, Destroyed in Southern Syria," *U.S. Central Command*, June 18, 2018, https://www.centcom.mil/MEDIA/PRESS-RELEASES/Press-Release-View/Article/1553512/14m-terrorist-drug-cache-seized-destroyed-in-southern-syria/.

should raise task forces to monitor dual use of neurotechnologies, particularly in the private sector, academia, and research centres.

Currently, there are no specific guidelines addressing unauthorised access to human neural functions, which poses risks to brain health and cognitive integrity. To address this gap, governments must update and expand the *Universal Declaration on Bioethics and Human Rights*, placing particular emphasis on the normative challenges arising from advancements in neurotechnologies. Establishment of active regulatory bodies, comprising neuroscientists and legal experts, is also essential. These bodies should be tasked with conducting comprehensive in-house reviews, ensuring ethical and medical compliance, and providing consistent oversight regarding feasibility and implications of employing neuroscience in military contexts.

Conclusion

While neuroweapons possess transformative potential, their impact is more likely to enhance existing military capabilities than to redefine warfare entirely. By enabling commanders to exploit asymmetrical gaps, these technologies will supplement, rather than replace, traditional combat systems. The enduring dominance of conventional strategic paradigms—centred on legacy systems like tanks, submarines, strategic bombers, and guided missile frigates—illustrates this point. Sustained investments in adapting these systems to new threats reinforce the notion that conventional warfare will continue to dominate for the foreseeable future. Consequently, integration of neuroweapons into military frameworks is expected to be a gradual process, positioning them as supplementary tools rather than revolutionary game-changers

Neuroweapons also face other challenges. Lack of long-term research, ethical concerns around informed consent and autonomy, and complexity of their operational mechanisms also make their integration into existing battle systems difficult. Moving

forward, addressing these challenges will require a multidisciplinary effort involving scientific, ethical, and policy-driven approaches. Understanding the doctrinal implications, operational utility, and potential countermeasures of neuroweapons will be critical to shaping their role in future conflicts. As technology advances, these issues will require continuous examination to ensure their use aligns with international norms and strategic objectives.

Military use of neurotechnologies will also complicate the existing battlefield by raising questions about attribution and response. While efficacy of neuroweapons below the threshold of an armed conflict makes them an effective asymmetric tool to inflict sizeable damage to the adversary's leadership and population, secrecy surrounding development of neuroweapons heightens uncertainty and mistrust, potentially driving other states to pursue neurodegradation capabilities and fuelling a neuroweapons arms race. To mitigate this risk, it is crucial to establish regulatory frameworks that limit the development of neurotechnologies for nefarious purposes.

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