Chemicals in Cognitive Warfare: A Peek Inside the Mind-Modifying Arsenal

Cassandra Granlund
The Norwegian Defence Research Establishment
NORWAY

cassandra.granlund@ffi.no

ABSTRACT

Cognitive warfare encompasses a spectrum of strategies aimed at influencing human thoughts, behaviours, and emotions, ranging from subtle forms of psychological manipulation to overt information operations. Within this landscape, neuroweapons, encompassing chemicals and pharmaceuticals targeting the human nervous system, have gained prominence as potential instruments of cognitive manipulation. This literature review seeks to delve into the multifaceted nature of cognitive warfare, focusing on the threats posed by chemical neuroweapons and their deployment in this context. The review is a preliminary work on the topic and sheds light on potential concerns that merit further investigation. It underscores the adversaries' capacity to exploit human vulnerabilities, at both individual and national levels. The review highlights the need for in-depth research to understand and counteract these potential neuroweapons, emphasising their significance in an evolving landscape of cognitive warfare.

1.0 INTRODUCTION

NATO ACT defines cognitive warfare as activities that, in coordination with other instruments of power, influence attitudes and behaviour by manipulating individual and group cognition to gain an advantage over adversaries [1]. In cognitive warfare, the human mind becomes the battlefield [2,3] aiming to exploit cognitive facets to disrupt, undermine, influence, or modify human and technological decisions [4]. According to NATO ACT, adversaries are increasing their cognitive warfare capabilities and employing cognitive attacks, which are offensive actions deliberately targeting the human mind to disrupt the Alliance by affecting perceptions, beliefs, interests, aims, decisions, and behaviour [1].

In an ever-evolving landscape of global conflicts characterised by their asymmetric and "grey zone" nature, the application of current and emerging neurocognitive science methods for manipulating human cognition and behaviour presents an immediate and growing challenge [5]. When neurocognitive systems are used as weapons, whether for defensive or offensive purposes against an opponent, they are broadly categorised as 'neuroweapons' [6]. Technological advancements have given rise to the development of biochemical, pharmacological, and direct energy neuroweapons capable of manipulating the human brain and central nervous system [7]. The objectives for neuroweapons in a traditional defence context (e.g., combat) may be achieved by altering (i.e., either augmenting or degrading) functions of the nervous system, to affect cognitive, emotional, and motor activity and capability [8].

Various chemical agents, which encompass a range of toxic chemicals, from industrial chemicals to pharmaceutical-based agents (PBAs), can be employed to achieve such altercation of cognitive functions. For example, pharmaceuticals and incapacitants can affect nervous system functions, including motor skills, perception, judgment, morale, pain tolerance, physical abilities, and stamina, all crucial aspects for combat [9–11]. Additionally, a wide array of factors and compounds can prove harmful or toxic to the central nervous system and human cognition. These encompass drugs, stress, diseases, toxic chemicals, and chemical substances. Xenobiotics, chemicals introduced to an organism's system outside its normal metabolic processes, play a pivotal role in this context [12,13]. Notably, many xenobiotic agents can induce neurotoxic effects. These effects can result from direct interactions between the compound and specific

targets within the nervous system, general damage to the tissue, or indirect impairment of neurologic function due to effects on other organ systems [14]. The central nervous system possesses limited regenerative capabilities, rendering even minor damage capable of yielding long-term consequences [15–17].

One key national security concern is the potential hostile exploitation of neuroweapons [18,19], combined with a creeping legitimisation of chemical weapons [20,21]. Moreover, advancements in and integration of science and technology across multiple disciplines, including chemistry, biology, information technology, mathematics, and engineering sciences, coupled with the rapid progress in the availability and power of enabling technologies, the widespread research capacity across the globe and to actors outside of a traditional research setting, can give rise to the misuse of knowledge. This misuse may, in turn, facilitate the creation of new chemical capabilities, which may conceivably lead to the development of novel neuroweapons [22]. Currently, neuroscience- and technology can be utilised to affect e.g., memory, learning, and cognitive speed; wake-sleep cycles, fatigue, and alertness; impulse control; decision-making; and trust and empathy [2,19]. Neuroethicist James Giordano put it, "It's not a question of if non-State actors will use some form of neuroscientific techniques or technologies, but when, and which ones they'll use" [22].

2.0 HISTORICAL USE OF CHEMICALS AS AGENTS OF WAR

Historically, military forces have used various substances including nerve agents, drugs, sensory stimulation, and sedatives to achieve diverse military objectives. These objectives range from incapacitating enemies to enhancing alertness using stimulants and conducting psychological operations that involve tactics like sleep deprivation and emotional manipulation [5]. Incapacitating agents (ICA) impair the performance of the central nervous system, are highly potent, and effective doses produce effects that last for hours to days without causing permanent injury or death [9–11]. ICA is designed in a military context to cause temporary disability on the battlefield [23]. An ideal incapacitant should induce rapid and reversible incapacitation without residual effects, ensuring survival and safety while allowing targeted deployment [24].

After World War II, there was a growing interest in incapacitating agents, particularly in the context of psychochemical warfare during the Cold War, which aimed to alter or impair brain function [25]. Compounds such as lysergic acid diethylamide (LSD) and methedrine were studied, but only 3-quinuclidinyl benzilate (BZ), a psychotomimetic agent, became a standardised weapon [26,27]. Psychotomimetic agents mimic psychosis symptoms, including delusions and delirium [28]. BZ, unlike earlier agents, was designed for temporary incapacitation, not lethality [28]. However, due to unpredictable psychological effects, LSD and BZ were considered unreliable for military use and were discontinued [24].

Numerous harmful chemicals, including fentanyl, have been weaponised or pose potential threats to cognition [29,30]. Fentanyl, an opioid anaesthetic and painkiller, has been a focus of military research since the 1970s, with studies on non-human primates to develop quick-acting incapacitating agents [31]. Fentanyl's lethality is comparable to that of organophosphorus nerve agents when used without medical support [32]. While opioid agents have not been extensively used in large-scale attacks, the Russian military employed synthesised fentanyl analogues to end a Moscow theatre siege in 2002, unintentionally causing over 120 deaths during the rescue operation [24,33]. In a continuing pattern, Russian authorities employed aerosolised synthetic opioids in 2005, suspected to contain carfentanil and remifentanil, as a response to a domestic terrorist group that had taken hostages [33,34].

Another class of incapacitating agents includes anticholinergic compounds, which can induce a range of effects such as blurry vision, sedation, hallucinations, memory problems, and confusion [35]. Scopolamine, known as "Devil's Breath," is an infamous anticholinergic drug often associated with myths about removing free will and the induction of a "zombie-like" state. In South America, it has been used for illicit purposes, including drug-facilitated sexual assault, robbery, and kidnapping [36,37]. Notably, the U.S. Embassy in Colombia issued warnings to visitors about the use of scopolamine for incapacitation and theft [38].

Additionally, chemicals have been used to improve cognitive functions, and throughout history, humankind has successfully used stimulants to boost alertness in military operations. One of the earliest examples dates to the Inca warriors' use of coca leaves many centuries ago. In more recent history, the military's use of amphetamine serves as a notable example [39,40]. The mass consumption of amphetamines and their psychoactive effects became particularly evident during World War II, where they played a role in facilitating warfare [41]. During the Vietnam War, the U.S. military consumed unprecedented amounts of drugs, leading to what is often referred to as the first 'pharmacological war'. These drugs included amphetamines, opium, barbiturates, and hallucinogens (Table 1). This widespread use was driven by the necessity of troops in highly stressful combat situations to self-medicate, find solace, and seek relief [39]. The Air Force continues to approve the use of amphetamine in specific operational scenarios [42].

3.0 CHEMICALS AS AGENTS OF COGNITIVE WARFARE

This paper aims to investigate the potential use of current and novel chemicals, particularly incapacitants, for the temporary or permanent modulation of cognition. This investigation is based on a literature review of open-published scientific literature, to shed light on the evolving landscape of chemical warfare tactics and capabilities. Table 1 summarises the main categories of chemicals and pharmaceutical-based agents which could be used in cognitive warfare. The continuous discovery of novel chemicals, with more potential structures than atoms in the universe, raises concerns about the ongoing possibility of weaponising toxic substances [29]. Furthermore, the misuse of artificial intelligence and drug-discovery software could lead to the creation of more toxic chemicals and pharmaceuticals [43].

Notably, new/novel/emerging psychoactive substances (NPS), unregulated by United Nations conventions, present potential public health threats [44]. These NPS categories include synthetic cannabinoids/cannabimimetics, new synthetic opioids, ketamine-like dissociatives, novel stimulants and psychedelics, as well as prescription and over-the-counter medicines [45,46]. NPS could be of interest in adversarial attacks due to their constant innovation and unregulated distribution. For instance, synthetic cannabinoids at higher doses can induce auditory/visual hallucinations, intense paranoia, and suicidal thoughts [47,48]. New synthetic opioids can trigger mood elevation, dysphoria, dissociation, and profound sedation [49]. Phencyclidine (PCP or "angel dust") can cause acute psychopathological symptoms, including memory impairments, reduced processing speed, anxiety, psychosis, and aggressive behaviour [45,50]. Designer benzodiazepines, more potent than Diazepam, come with side effects such as amnesia, prolonged confusion, dizziness, loss of coordination, drowsiness, blurred vision, slurred speech, and ataxia [51].

Investigating pharmacological agents intended for incapacitation may also reveal how manipulation of similar mechanisms can be employed to improve, rather than degrade, human performance. The military invests significant resources in research and development to optimize performance in the face of environmental and operational stressors, as well as to amplify performance beyond existing capacities [52,53].

Human performance-enhancing drugs include high doses of caffeine and synthetic stimulants such as amphetamine, methylphenidate (Ritalin), and modafinil. Stimulants enhance alertness, attention, concentration, and energy while boosting mood, heart rate, and blood pressure. Other human enhancement drugs include mood and behaviour enhancers such as Diazepam and low doses of GHB, and culturally accepted drugs in Western society such as caffeine and nicotine [54,55]. Drugs with novel mechanisms that modulate the action of neuroreceptors, such as ampakines and hypocretin, are promising cognitive enhancers that can improve memory, cognitive performance, and alleviate exhaustion due to sleep disorders [56,57].

However, large increases in dosage or frequency of stimulants would lead to an increased risk of toxicity and adverse effects. The positive outcomes from stimulant consumption are often overshadowed by the negative side effects and incorrect dosage [54]. Additionally, no single cognitive enhancer can augment every cognitive function, and most cognitive enhancers have specific profiles regarding their efficacy for different cognitive domains.

Table 1. Selected potential chemical agents/pharmaceutical-based agents that can impair or enhance cognitive functions and/or alter emotional states and threat summary [35,52,58,59].

Chemical Agent	Examples	Effects/Side Effects	Used
Anticholinergics	Include atropine, scopolamine, tricyclic antidepressants, and antipsychotics.	Memory problems, confusion, less ability to concentrate, blurry vision, rapid heart rate.	Atropine autoinjector has been in use since 1973 (U.S.) for the treatment of exposures to chemical warfare nerve agents and insecticides [60].
Calmatives/depressants	Include sedative-hypnotic agents (e.g., benzodiazepines, barbiturates), anaesthetic agents, skeletal muscle relaxants, opioid analgesics, antipsychotics, antidepressants, and anxiolytics.	Diverse, can include deep sedation, hypnosis, and lethal overdose.	Synthesised fentanyl analogues used in the Moscow theatre siege in 2002, killing over 120 hostages [61].
Hallucinogens/ psychedelics/ neuroleptic anaesthetics	LSD, psilocybin, peyote, DMT, dissociative agents (PCP, ketamine), NPS, salvia.	Profound changes in auditory and visual perception, the experience of time or space, alterations in moods, thoughts, judgment, memory, and other mental states. Can cause paranoia, psychosis, disorientation, memory loss, seizures, and depression.	In present-day conflicts by members of ISIS, Al-Qaeda, the Taliban, Chechen fighters, Somali militants, rebel groups in Liberia, Sierra Leone, Uganda and the Democratic Republic of the Congo, combatants make use of psychoactive substances in an attempt to compensate for limited military training and technology [40].
Human performance-enhancing drugs	Stimulants. High doses of caffeine, nicotine, amphetamine, methylphenidate (Ritalin), atypical stimulants (modafinil), mood and behaviour enhancers (e.g., Diazepam and low doses of GHB).	Enhance alertness, attention, concentration, and energy while boosting mood, heart rate, and blood pressure.	Microdosing psychedelics to enhance cognitive performance, mood, energy, and creativity [62]. Mass consumption of amphetamines during World War II [41], used by American troops in the Vietnam War and the Gulf War in the 1990s, and currently used by the U.S. Air Force in specific operational scenarios [63].

Chemical Agent	Examples	Effects/Side Effects	Used
Psychotomimetics	Cannabis, BZ.	Dose-dependently induces a psychosis or schizophrenia-like illness, often including hallucinations and delusions in normal individuals. Implicit in this term is a mimicking of naturally occurring psychosis.	BZ was tested on human subjects in Utah under the codename "Project Dork" in the early 1960s and later in Hawaii between 1966 and 1967 [64]. BZ was subsequently weaponised until stocks were destroyed in the early 1990s [65].
Riot control agents	CN, CS, PS, CA, CR, and combinations of various agents.	Irritate eyes, mouth, skin, and upper respiratory system.	World War I, Vietnam War, Iran-Iraq war, currently commonly used by law enforcement agencies and military [66].
Neurotoxic compounds	Organophosphate pesticides, heavy metals, DDT, ethanol, PCBs, mercury/methylmercury, lead, fluoride, arsenic, polychlorinated biphenyls, PAHs, flame retardants.	Long-term adverse health effects, including neurological and psychiatric disorders affecting attention, memory, developmental malformation, endocrine disruption, and cognitive functions.	Methylmercury causing Minamata disease [67], and exposure to air pollution's particulate matter can lead to lower IQ test scores in toddlers [68].

4.0 THE APPLICATION OF CHEMICALS IN COGNITIVE WARFARE

It is important to note that any country with a chemical industry possesses the capability, if not the desire, to manufacture toxic chemicals. Many of the technologies involved in this process are well-documented in publicly available literature [69].

The invasion of Ukraine by Russia in February 2022 has given rise to significant concerns regarding Russia's capabilities in producing chemical weapons, expanding its nuclear capabilities, and undermining international non-proliferation efforts. Furthermore, Russia's attempts to shield the Syrian government from accountability for chemical weapons use and its attacks on the credibility of the Organisation for the Prohibition of Chemical Weapons (OPCW) have added to these concerns [21]. Consequently, unlike other recent conflicts in Libya, Afghanistan, and Yemen, the threat of chemical (including pharmaceutical-based) and radiological weapons use by state actors in the current geopolitical landscape is higher than ever [21, 70]. The chemical weapon threat is evolving and multifaceted, encompassing military-grade agents, novel incapacitating agents, and toxic industrial chemicals (TICs). Chemical weapons' operational significance is their primary physiological effects, which include incapacitation and lethality, and secondary effects such as economic damage through land, machinery, and crop contamination, as well as psychological and social impacts. The psychological consequences of chemical weapon use are particularly important, as they can have a more significant strategic impact than the primary effects due to the distinct terror they evoke [71].

Unconventional warfare strategies that encompass cognitive manipulation and hybrid warfare tactics can include a range of methods. These methods span from exposure to neurotoxic substances to the introduction of psychoactive compounds into food supplies, along with the utilisation of metallic nanoparticles and radiation [73,74].

Recent advancements in warfare techniques and a better understanding of neural behaviour and cognitive processes have created opportunities for both beneficial applications, like medical interventions, and potentially harmful uses. Additionally, advancements in drug administration methods have opened new possibilities for deploying agents effectively. The success of deploying an agent depends on two critical factors: dissemination, which involves transporting the agent to the vicinity of the target, and uptake, which is the agent's movement to its active site within the target [63].

Various methods can be employed to administer agents, including direct injection, ingestion, topical application, and inhalation. Of particular interest is the pulmonary route due to its targeted drug delivery capabilities [63,76]. Aerosolised dissemination of incapacitating agents offers flexibility for different operational requirements, from large-scale open-air dispersion in battlefield scenarios to localised dispersal through ventilation systems for counterterrorism or hostage rescue missions.

The impact of cognitive attacks is considerable, as they have the potential to influence the decision-making abilities of military personnel and leaders, possibly resulting in incorrect or less-than-ideal decisions [1]. In theory, chemical agents, including pharmacological substances, could be used covertly against military and political leaders to impair their decision-making abilities or manipulate them psychologically [75]. Advances in neuroscience may also open new avenues for controlling populations and modifying behaviour temporarily, potentially preventing riots and ensuring compliance with state policies [74].

Certain substances, like LSD and BZ, attracted the attention of the U.S. military, leading to stockpiling efforts in the 1960s. Historically, the Joint Non-Lethal Weapons Directorate (JNLWD) explored the delivery of microencapsulated psychoactive drugs through various means, including shotguns, airburst munitions, or drones [76]. Nevertheless, these substances became obsolete, and no direct replacements have emerged. Presently, microencapsulation is being reconsidered as a promising technique for improving the stability, penetration, and controlled release of chemical agents, with ongoing research focused on its application in delivering incapacitating agents [77,78]. Microencapsulation involves enveloping a chemical agent microdroplet with a biodegradable polymer, drawing parallels with techniques used in pharmaceutical products for targeted drug delivery. Dissemination can be achieved by creating an aerosol cloud capable of penetrating the respiratory tract, causing the envelope to dissolve and release the chemical agent [77,78].

Calmatives, such as barbiturates and benzodiazepines, have also been considered for incapacitation, with possible delivery methods including adding them to drinking water, topical application, aerosol spray inhalation, or incorporation into drug-filled rubber bullets [79]. While these substances offer potential military advantages, the practical application of calmatives and other pharmaceutical agents for such purposes faces various challenges.

The controlled delivery of chemical agents remains a key challenge for those who seek to develop chemical neuroweapons. Notably, there are several crucial differences between drug delivery in clinical and weaponised contexts [63]. These challenges include delivering the right concentration and effects (dose-response), managing unpredictable outcomes, and considering a drug's therapeutic index. It is important to note that even when the therapeutic index, which measures the safety margin by comparing the lethal dose to the effective dose of a drug, is presumed to be safe, it may not guarantee safety, as evidenced by the Moscow theatre operation.

In an operational context, there are additional difficulties in developing a safe chemical agent. Variables like the diverse body masses, health conditions, and ages of the target population, along with the potential for secondary injuries and the need for medical aftercare, make uniform dosing on a large scale challenging and result in varied clinical effects among mass casualties [33].

Another significant challenge to targeting the brain and cognition is overcoming the blood-brain barrier, which restricts the passage of many molecules and microorganisms from the bloodstream into neural

tissue. The blood-brain barrier protects the brain but poses challenges for delivering certain chemicals. Advances in nanotechnology-based drug delivery systems show promise in delivering peptides to the brain, potentially opening new possibilities for controlled incapacitation agents, or novel adverse neuroweapons [63,80,81].

There is a growing concern about the potential weaponisation of substances previously considered non-lethal, particularly with the advancements in drug delivery technologies like nanomedicines and nanoparticles designed to target specific cell types [63,82]. The idea is that developing nanoparticles for precise cell targeting could enable the use of toxic chemicals as weapons. However, assessing this concern by monitoring progress in nanomedicines poses challenges. Nanoparticles used in medicines are limited due to the need to minimise drug toxicity and side effects. Additionally, medical nanoparticle delivery occurs under controlled conditions, controlled doses, and medical supervision, which is different from the requirements for dispersing nanoparticles as weapons. Moreover, the reproducibility of nanomedicine research is a challenge, even in accredited facilities. Therefore, the current state of nanomedicine is unlikely to pose a threat to international agreements like the Chemical Weapons Convention [76,83,84]. However, the field of nanocarriers for drug delivery is rapidly advancing and should be closely monitored. While the application of this research in adversarial development of chemical and pharmaceutical-based neuroweapons, is uncertain, special attention should be given to developments in pulmonary drug delivery systems using nanocarriers, as there is potential for weaponising aerosols [84,85].

5.0 REGULATION OF THE USE OF CHEMICALS AS WEAPONS

United Nations Security Council resolution 1540 (2004) mandates UN member states to establish domestic controls to prevent the proliferation of nuclear, chemical, or biological weapons and their delivery systems [86]. Member states are required to exercise export control to hinder such proliferation. Additionally, States Parties to the Chemical Weapons Convention (CWC) must adopt measures to implement their obligations under the convention, including declaring activities involving scheduled chemicals to the OPCW. The CWC bans the development, production, acquisition, stockpiling, transfer, and use of chemical weapons (as defined by the convention) and requires all possessor states to destroy their stockpiles. The OPCW serves as the implementing body of the CWC and inspects and monitors State Parties' facilities and activities relevant to the convention to ensure compliance [87].

The Single Convention on Narcotic Drugs (1961), as amended by the 1972 protocol, and the Convention on Psychotropic Substances (1971) impose control measures on scheduled drugs [88,89]. The 1925 Geneva Protocol prohibits the use of chemical and biological agents and weapons in warfare, to prevent the repetition of atrocities witnessed during World War I [90]. Importantly, the Geneva Protocol of 1925, like earlier agreements, was an arms control agreement rather than a disarmament treaty. It banned the use of chemical and biological agents in war but did not prohibit their development, production, research, or possession.

Certain states ratified the protocol with conditions, such as the United States, which made its commitment contingent on the protocol's binding nature being upheld only if enemy states or their allies adhered to the prohibitions. Conversely, the Soviet Union ratified the protocol with the condition that it would only be binding on states that ratified or acceded to it. To address such issues, the Biological Weapons Convention (BWC) of 1972 and the CWC of 1993 were introduced as supplements to the protocol [20,87,91].

The CWC defines "chemical weapons" as toxic chemicals and their precursors except where intended for purposes not prohibited under this Convention; munitions and devices designed to cause death or other harm through these toxic properties; and equipment associated with such munitions and devices. A "toxic chemical" is defined as any substance that can cause death, temporary incapacitation, or permanent harm to humans or animals through its chemical action on life processes, regardless of its origin or production method. Additionally, the CWC outlines the category of "Riot Control Agent," which includes chemicals

that produce sensory irritation or disabling physical effects rapidly in humans and dissipate shortly after exposure. The convention also specifies "Purposes Not Prohibited Under this Convention," which encompass various peaceful, protective, and law enforcement applications, excluding the use of chemical weapons for warfare purposes [87].

Thus, except when intended for purposes not prohibited under the CWC and as long as the types and quantities are consistent with such purposes, the convention explicitly prohibits production, acquisition, stockpiling, transfer, and use of toxic chemicals – including chemicals not listed on a schedule in the CWC Annex on Chemicals. Therefore, it comprehensively covers all hostile uses of agents, existing and future ones, which rely on toxicity to cause harm. Two of the purposes not prohibited under the CWC are the use of chemicals for industrial, agricultural, research, medical, pharmaceutical, or other peaceful purposes, as well as their use by law enforcement, particularly as domestic riot control agents (RCA). While the use of RCAs as weapons in warfare is strictly prohibited, their manufacture, stockpiling, and use for domestic riot control purposes are permitted, provided they comply with the defined types and quantities.

However, concerns have arisen regarding the potential misuse of pharmaceuticals and other chemicals when developed, manufactured, stockpiled, and used by law enforcement. There is a grave concern that these activities might serve as cover for the development of pharmaceutical-based agents, particularly central nervous system-acting chemicals (CNS-acting chemicals), as new types of chemical agents. In response to this concern, the Conference of the States Parties to the CWC decided in 2021 that the aerosolised use of CNS-acting chemicals is inconsistent with law enforcement purposes as a "purpose not prohibited" under the convention.

Biological and chemical weapons control has traditionally been viewed as a balancing act between the desire to 'completely eliminate' the possibility of such weapons being used and the need to promote, or at the very least not obstruct, socially beneficial applications of chemical and biological sciences and technologies [20].

6.0 FUTURE PERSPECTIVES ON THE WEAPONISATION OF CHEMICALS

While the CWC allows the development, production, and stockpiling of toxic chemicals for various peaceful purposes, including pharmaceuticals, there is a risk of misuse and weaponisation, particularly in the context of hybrid warfare. The Center for the Study of Weapons of Mass Destruction has raised concerns that by 2030, chemical agents may become more accessible to both state and non-state actors due to reduced barriers to acquiring relevant technologies. These agents could become more capable in terms of defeating defensive countermeasures and evading import/export control measures. Additionally, there may be advancements in non-lethal techniques that require higher specificity, safety, and reversibility to avoid causing lasting impairment [92,93].

In contrast to the chemical warfare agents of WWI, the modern landscape of hybrid warfare involves the potential use of a wide range of chemicals to alter cognition and behaviour at both individual and societal levels. A significant challenge in weaponising pharmaceuticals is ensuring effective delivery and uptake of the agent. Therefore, it is crucial to closely monitor pharmaceutical developments and drug delivery systems that can enhance drug penetration of the blood-brain barrier, improve precision in drug delivery, evade immune defences, bypass metabolism, or prolong cellular and downstream effects.

Moreover, advancements in drug delivery technologies may enable the use of certain peptides and brain proteins as drugs in the future, making it important to develop antidotes or protective agents against various classes of pharmaceuticals that could be exploited by enemy forces. Further, bioregulators are now considered promising incapacitating agents, and scientific teams worldwide (for example, in the United States, Great Britain, France, Russia, China, and Israel) are actively researching them, heightening the potential for their use [77]. Bioregulators are natural organic compounds that play a vital role in regulating

various cellular processes across all organisms. They govern essential biological functions such as blood pressure, respiration, mood, emotions, immune responses, and sleep. The primary bioregulator groups include cytokines, eicosanoids, neurotransmitters, hormones, and proteolytic enzymes [90]. Furthermore, endorphins and enkephalins, known as "hormones of happiness," are bioregulators that can block pain or induce feelings of contentment when released during physical stress [73,97]. For instance, Swedish Defence Research Establishment research on aerosolised peptide Substance P suggests the possibility of engineering more stable aerosolised bioregulator molecules capable of breaching the blood-brain barrier [94–96]. If successful, bioregulators could induce sleep, sedation, or calmness, with potential applications in law enforcement, counterterrorism, and urban warfare [63,98].

However, the utilisation of neuroweapons raises profound ethical and practical concerns that warrant careful consideration. Firstly, one of the critical challenges in the development and deployment of neuroweapons is the controlled delivery and uptake of these agents. Secondly, the dual-use nature of neuroscience research presents a formidable challenge. It raises concerns about how rapidly evolving drug development and delivery systems could enable novel ways to target the human brain and neural systems [99,100]. This not only lowers the barriers to acquiring relevant technologies but also poses a threat to existing countermeasures against chemical weapons. The very advancements that hold great promise for medicine and science can be leveraged for harmful purposes, necessitating a delicate balance between scientific progress and ethical considerations. There should be a holistic approach that considers both the existing and emerging threats while acknowledging the practical capabilities and limitations of science and technology in the realm of chemical warfare.

7.0 CONCLUSION

Chemical agents have been used in warfare for a long time, but the integration and convergence of multiple technological advancements and the expanding accessibility of information and technology have led to the emergence of new attack vectors in cognitive warfare. Cognitive warfare aims to change and mould how people think, act, and make decisions, elevating well-known methods used in warfare to a new level. Neuroweapons, available to both state and non-state actors, can be used in military operations to degrade the physical, psychological, and physiological performance of allied forces and hostile terrorists. The disruptive potential of neuroweapons extends from individual cellular functions to societal and geopolitical levels, highlighting the urgency of ethical and policy considerations in this field.
Based on findings in openly available scientific literature, there is evidence to suggest that adversaries can employ chemical and pharmaceutical-based agents as attack vectors to achieve their objectives in cognitive warfare. The adversaries often operate within different ethical boundaries than liberal democracies, creating significant asymmetries. NATO ACT states that "currently, there are shortcomings in NATO's ability to protect against cognitive attacks with implications for NATO's deterrence and defence posture [1]. Therefore, it is imperative to enhance our understanding of how adversaries may employ novel approaches to target human cognition through chemical agents. This understanding is crucial for the development and validation of countermeasures and defensive strategies, enabling the preservation of national and NATO situational awareness and cognitive superiority.

In conclusion, ongoing vigilance, comprehensive research, and international collaboration are of paramount importance when navigating the intricate landscape of cognitive warfare and the utilisation of neuroweapons. This collective effort is essential not only for the protection of military personnel but also for the preservation of global security and the upholding of ethical standards in the face of evolving threats.

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