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Review Article

Military Brain Science — How to influence future wars

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ABSTRACT

Military Brain Science is a cutting-edge innovative science that uses potential military application as the guidance. It was preliminarily divided into 9 aspects by authors: understanding the brain, protecting the brain, monitoring the brain, injuring the brain, interfering with the brain, repairing the brain, enhancing the brain, simulating the brain and arming the brain. In this review, we attempt to propose the concept, content and meaning of the Military Brain Science, with the hope to provide some enlightenment and understanding of the research area.

Background

Brain science is an interdisciplinary emerging research field with the brain as the study object. It is a science that studies the nature and law of cognition and intelligence. The human brain has 100 billion neurons, which are connected by a large number of nerve fibers to form a complex neural network; however, our current understanding of the brain is only a drop in the ocean. Since 2013, many important programs have been launched worldwide in the field of brain science. Among them, the Brain Research through Advancing Innovative Neurotechnologies (BRAIN)[1] program in the United States aims at exploring the activity and function of every neuron in the human brain in order to draw a detailed atlas of the activity of the neurons in the brain; this program is also called the "whole-brain neuron map" program. The aim of the "Human Brain Project" (HBP)[2] from the European Union is to provide fine modeling and simulation of the function of the human brain using a supercomputer. The study aim of China's "Brain Project" can be summarized as "One body, two wings", with the study of the neural principles of brain cognition as the "main body", and the research and development of novel means for the diagnosis and treatment of important brain diseases and new technologies for brain computational intelligence as the "two wings". The brain science craze, which started in the leading nations of science and technology, is very likely to become another "human genome project", leading to another peak in scientific research over the next several decades, and some scientists have even vividly referred to brain science as the "last frontier in science".

Thus, the seeds of the "brain science program" in the United States, the European Union and China have been subsequently "sown" and "germinated". The outline for the future has essentially been determined. However, the study of Military Brain Science (MBS) in the world is still in the initial stages of waiting for "seed selection" and "seeding". At present, existing studies have more or less set the foundation for the field of MBS; however, in general, the study aims are not clear, the theoretical discoveries are not systematic, the technology applications are not mature, and many studies are ethically controversial. In this paper, we attempt to take the lead to propose the concept, content and meaning of MBS, with the hope to provide some enlightenment and understanding to the related people.

Concept

MBS is a cutting-edge innovative science that uses potential military application as the guidance. It is based on the theories and technologies of clinical medicine, basic medicine, military medicine, biology, physics, computer science, military science and multiple other disciplines, and it studies various military activity-related

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brain activity patterns and their influencing factors, with the aim of monitoring the brain, protecting the brain, fighting against the brain, repairing the brain, enhancing the brain and other military-related research goals through various methods (Fig. 1).

Content

The present review for the first time proposes an MBS classification of brain functions that are closely related to actual combat capabilities, which are preliminarily divided into the following 9 aspects: understanding the brain, protecting the brain, monitoring the brain, injuring the brain, interfering with the brain, repairing the brain, enhancing the brain, simulating the brain and arming the brain.

Understanding the brain—be clear about the risk factors of brain injury caused by military activities

This aspect involves understanding the ultrastructure of the brain and its connection methods and understanding the neural circuit basis of various functions of the brain (including advanced functions). At present, many brain functions and their influencing factors have not been elucidated. For example, how does the brain make a judgment and a decision about the external environment? How does the brain create an alarm reaction to a dangerous environment? How does the brain control the motions and emotions of fear? Studies have suggested that environmental space,[3] magnetic fields,[4] the shockwave of external forces,[5] etc can all have an impact on brain activities. The potential impacts include the damage to brain tissues caused by staying in a complex electromagnetic environment for a long time; the impact of long-term navigation operation in a closed space of a cabin on the cognitive ability of the brain; the brain damage caused by an underwater explosion shockwave of each station personnel of surface ships or underwater submarines during naval battle[6]; and the impact of post-traumatic stress disorder in the battlefield on the mental state and combat effectiveness.[7] These unknown problems have put forward a large number of research topics that need to be answered to understanding the brain.

Protecting the brain—targeted prevention of the brain damage caused by military activities

On the basis of understanding various known brain damage risk factors and the possible unknown risk factors, targeted preventive measures are proposed. In terms of equipment, a series of brain protection equipment should be researched and developed, such as anti-shockwave helmets, helmets to protect against electromagnetic weapons, dazzle laser defense spectacles, harmful sound wave defense earplugs and other brain damage protection equipment. In terms of drugs, brain nerve protection agents and brain function stabilizing agents that have independent intellectual properties should be researched and developed. In terms of measures, targeted brain protection methods and measures should be studied, and early post-trauma brain protection and treatment measures should be investigated to minimize brain damage to the greatest extent. In terms of strategies, establishing a Forward Surgical Team (FST) composed of neurosurgeons, anesthesiologists, and emergency physicians should be studied and evaluated. According to future battlefield conditions, a brain protection and treatment team should be set up to achieve the goal of protecting the brain.

Monitoring the brain—monitoring brain function through new technologies and equipment

The functional state of the brain is one of the decisive factors on the battlefield. Many questions about monitoring the brain need a clear answer. For example, after experiencing an intensified mental stress on the battlefield, will cognitive abnormalities such as indecisive execution of tasks and mistakes in decision making occur? Will the personnel still be competent after working continuously and exhaustedly or after having a mild brain trauma? What are the trends in the changes in a disease condition after brain injury? For these questions, we can use wearable nerve signal detection technology, voltage-sensitive molecule and nano-fluorescent probe technology, body fluid nerve marker detection technology, various behavioral assessment and detection software, and various brain function and nerve imaging methods.[8–10] We should monitor brain fatigue, monitor the brain decisions of individuals in special and sensitive posts, continuously monitor individuals with brain trauma and perform other forms of brain function monitoring and assessment.

Injuring the brain—promoting the research and development of sound, light, explosion, magnetic and other new types of weapons

People are the key to victory or defeat in war, whereas the brain is the “headquarters” of the human body. Precisely attacking the “headquarters” is one of the most effective strategies for determining

Fig. 1. Military Brain Science is a cutting-edge innovative science that uses potential military application as the guidance. It can bring a series of fundamental changes to the concept of combat and combat methods, creating a whole new "brain war" combat style and redefining the battlefield.

victory or defeat on the battlefield. When researching and finalizing various weapons and equipment, in addition to the killing energy of the arms and the destroying effect of an enemy's equipment, the biological killing effect of the combatants should also be considered. This research includes the study of the damaging effects to sensitive target areas of brain tissues by acoustic weapons,[11] laser weapons,[12] high-explosive weapons,[5] and electromagnetic weapons; the study of the pattern and characteristics of the morphology, structure, function and development of the brain; and the study of establishing the relationship between weapon parameters and their killing effects. The analysis of brain damage can provide feedback to enhance the research and manufacture of weapons, and research on the injury target will promote the innovation and development of weapons, providing new theoretical support for future battlefields.

Interfering with the brain—causing brain dysfunction and a loss of control with the "smokeless" method

According to the physiological basis of the transfer of brain nerve potentials and the transmission of chemical transmitters, nervous system incapacitating agents and body incapacitating agents will be developed, including brainwave interference weapons; according to the inherent frequency of brain tissues, infrasound weapons will be developed to interfere with brain tissues and cause insanity through resonance[13]; according to the cognitive characteristics of the enemy population, psychological tactics will be used to interfere with the original beliefs and thought of the brain, causing psychological injury to the enemy, decreasing their will for combat or even promoting voluntary surrender[14]; and according to the unique advanced activity characteristics of the brain, noises, beeps and other special sounds will be developed to interfere with the brain and produce fear, depression, dysphoria and other emotions that reduce combat effectiveness. The strategy of interfering with the brain can affect mentality, influence thinking, and affect decision making to create a whole new "brain war" combat style and redefine the battlefield.

Repairing the brain—achieving brain function reconstruction with advanced novel medical technology

After brain tissue suffered from various injuries, during the acute phase after the injury, neurosurgery and other early interventions are needed for treatment, and the repair methods include trauma control treatments. The chronic symptoms caused by brain trauma, such as post-traumatic stress disorder, blindness, deafness, limb hemiplegia, and long-term coma, are still the difficult issues in the brain repair field.[15,16] In recent years, regenerative retinas,[17] artificial cochlear implants,[18] deep brain stimulation,[19] mechanical prosthetics[20] and other advanced new technologies and equipment have been experimentally applied in this field and have brought unprecedented hope to the issues that cannot be solved by traditional clinical medicine. We should further innovate brain injury-related treatment concepts and conduct research in the fields of nerve substitution transplantation, electronic nerve elements, regenerative medicine and intelligent prosthetics to restore the function of the brain and other target organs.

Enhancing the brain—improving the level of the brain function of personnel who carry out special tasks

Some military tasks are urgent and important, and some posts lack competent personnel or have combat casualties. Under these conditions, it is necessary to enhance the brain function of the existing personnel who carry out the tasks in order to complete the task. We should investigate the mechanisms and technologies that enhance brain function through sound, light, electricity, magnetism and other various means; carry out transcranial magnetic stimulation technology-based research to improve and enhance cognitive function[21]; investigate "target memory reactivation" technology under a sleep state[22]; develop brain fatigue warning and intervention products; develop side effect-free anti-fatigue drugs; and develop drugs that can improve soldier's cognition and operational abilities. We need to comprehensively improve military personnel's brain functions and cognitive abilities to create "super warriors".

Simulating the brain—brain-inspired robot intelligence and predicting human decisions

By simulating the brain's decision-making processes and its neural mechanisms, brain-inspired chips and robots that combine visual, auditory, thinking and execution abilities will be developed and will be used to partially substitute for soldiers in combat in the future. Brain-inspired robots should have face recognition, enemy identification, judgment of an enemy's situation and other advanced brain functions to execute special high-risk combat tasks.[23,24] Another frontier task for "simulating the brain" is to predict human decisions by collecting a large amount of data, including growth history, military background, drill information, decision-making habits and battlefield dynamics. Through logical reasoning analyses, the possible decision-making ideas of an enemy's commander can be automatically speculated, allowing opportunities on the battlefield to be seized. Research on "simulating the brain" can make weapons more intelligent and more dangerous, allowing an enemy's decision-making ideas to be known and used by us.

Arming the brain—studying the arming of the brain, with brain and machine interfaces as the focus

The Defense Advanced Research Projects Agency (DARPA) of the United States launched the "Avatar" project in 2013, which intended to create a robot combat corps that was remotely controlled by the human brain using brain-machine interface technology. China has also established the basic conditions for brain science-related research in the fields of electroencephalogram information processing, bidirectional alternation of multi-technology integrated brain-machine interfaces, the neurobiology principles and mechanisms of the coupling and integration of brain-machine interfaces, and non-human primate animal resources, and China should seize this historic opportunity. The focus is to study the direct bidirectional technology between the brain and radar detection systems, command systems, weapon systems and other external equipment to achieve the effect of "perception is decision making, decision making is attack" and to study the "brain-land-sea-space-sky" global combat mode.

Goals and significance

"The key to victory or defeat in war is people", whereas the key to people lies in the brain. Through the study of MBS, we can achieve the military-related capability goals of monitoring the brain, repairing the brain, enhancing the brain, simulating the brain, and arming the brain and achieve the military goal of creating a whole new "brain war" combat style and redefining the battlefield.

The significance of MBS research lies in the following:

MBS can reshape the battlefield

Injuring the brain, interfering with the brain and enhancing the brain can bring a series of fundamental changes to the concept of

combat and combat methods, creating a whole new “brain war” combat style and redefining the battlefield. Arming the brain will inevitably lead to the establishment of the command system known as “perception is decision making, decision making is attack”, which will establish a whole new “brain-land-sea-space-sky” global combat mode.

MBS can promote innovation

As an emerging scientific field, MBS-related research covers a large number of projects in our army and our country, which have a very weak foundation; this will inevitably promote innovation in related studies. Researchers should break from the shackles of traditional knowledge and inherent concepts, should be creative, and should face challenges to achieve important scientific discoveries, technology invention, principle-oriented technology and other innovative results.

MBS can lead to military and civilian integration

First, there are “civilian joining the army”. To make military brain program research successful, researchers at the Chinese Academy of Sciences, Tsinghua University and other top domestic academic institutions must be involved in order to integrate and optimize the military and local resources. Second, there is “converting the military into civilians”. MBS research technology and methods are also suitable for non-military-related brain science research, and the expected research results of MBS also have many applications in civilian fields.

Conclusion

Innovation is always an important force in the development of a country, a nation. If we do not recognize changes, respond to changes and make changes, we may fall into strategic passiveness, miss opportunities for development, or even miss an entire era. We predict that MBS will inevitably become a new focus of military competition between the leading nations of the world in the coming years. Relevant departments should begin top-level designs quickly, mobilize the best resources within or outside the military, integrate interdisciplinary powers, reserve compound talents and lead the development of MBS in the area.

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Appendix A. Supplementary data

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