

OPPORTUNITIES FOR THE DEVELOPMENT OF MILITARY COGNITIVE SKILLS II (PRACTICAL APPROACH)

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ABSTRACT:

In the first part of the series of articles, we dealt with the theoretical foundations of cognitive intelligence, including primarily the possibilities of increasing military cognitive performance and the relationship between AI. Every military in the world uses some form of general cognitive intelligence assessment to place recruits in the right jobs. In the assessment, one form of examination is the examination of cognitive ability. The purpose of this article is to explore whether military cognitive intelligence assessments can actually work. Accordingly, in this second part, after the theoretical approach of the first part, we want to prove our hypothesis with practical examples, according to which cognitive intelligence can decisively influence the execution of tasks in armies, so it can be a decisive condition for successfully fighting a war.

KEYWORDS:

Artificial intelligence, automation, cognitive intelligence, military application

1. Introduction

A leading example of military cognitive development is the US Department of Defense, including the Army, Air Force and Navy. The Defense Advanced Research Projects Agency (DARPA), which has been involved in cognitive development research and development for more than a century, has developed new strategies in medicine, nutrition, neuroscience, education, technology and sleep-related development that can be applied to the military.

2. Research results, situation

The overall goal of the ongoing research is to identify safe, reliable and robust strategies and technologies that can help soldiers gain the upper hand by

detecting threats, enhancing situational awareness and facilitating decision making. Let's take a look at where the U.S. Army is in its research that explores a range of approaches to cognitive development. Military research aims to target neural mechanisms and processes that directly influence higher-level task performance. Advances include transcranial electro stimulation (TES), augmented reality (AR) and targeted skill development (Porkoláb & Négyesi, 2019; O'Hanlon, 2019a).

Within the US military, cognitive development research is primarily managed by Headquarters Departments of the Army (HQDA) under the Army Futures Command (AFC). These organizations, on the HQDA listing sheet, include: "Army Behavioral and Social Research Institute

(ARI), Combat Capabilities Development Command Center (CCDC SC), Data and Analysis Center (CCDC DAC), Army Research Laboratory (CCDC ARL) and the Weapons Center (CCDC AC). These include Medical Research and Development Command (MRDC) laboratories, including the United States Army Research Institute of Environmental Medicine (USARIEM), the US Army Aeronautical Research Laboratory (USAARL), and the Walter Reed Military Institute of Research (WRAIR)”.

More than 15,000 scientists and engineers work in these organizations, many of them on solutions to improve the cognitive performance of soldiers. The primary goal of the research is to find out by what means military supremacy can be achieved, primarily by strengthening the effectiveness of situational awareness. Solutions include enhancing training and skill acquisition, providing targeted assessment and feedback, and increasing vigilance and threat awareness. The diversity of research topics means that the research is multidisciplinary in nature and thus the research activities of the Defence Research Group span cognitive, affective, social and behavioural sciences. In addition, they draw on expertise in robotics, informatics and biomedical engineering. Much of the research and development in the US military is carried out by defence scientists and engineers, but the organizations periodically call on collaboration with academia and industry to support their work (NATO, 2020; Zhang et al., 2017).

The importance of research is reflected not only in the many organizations and large research staff listed, but also in the diversity of research topics, which has resulted in a wide range of basic and applied research programmes funded by the US military. While these represent only a small portion of the internal efforts of the US Army, nine research areas are briefly described below that may serve as examples for future research with a focus on cognitive enhancement:

➤ *Measuring and Advancing Soldier Tactical Readiness and Effectiveness (MASTR-E)*

Aims: To measure and promote the tactical readiness and effectiveness of soldiers. To improve the soldiers' weapons, mobility, communication and decision-making skills.

To date, quantifying the performance of collective small units in an operational environment remains a major challenge for both military scientists and technologists. This is due to the complexity of the operational environment and the high degree of variability in the supplies, equipment and operational outcomes that can be used for missions (Li, Ota & Dong, 2018; Paisner, Cox, Maynard & Perlis, 2014). Although the proliferation of commercially available wearable sensors has increased the ability to capture and measure large amounts of data in the field, the interpretation and use of this data is still severely hampered by a lack of understanding of which aspects of performance are worth quantifying in combat environments. The task is therefore a given, but until quantitative performance measures are developed that directly correlate with mission execution quality and operational outcomes, the interpretation of data and the use of models that can be derived from the data to guide decisions will remain severely limited for implementers.

➤ *Biomedical Performance Enhancement*

Aims: Biomedical performance enhancement, development, validation and dissemination of biomedical strategies to improve the health and readiness of individual warriors, including cognitive function.

The research conducted by the MRDC aims to develop biomedical strategies to improve the health and fitness of individual warriors and their cognitive functions through biomedical performance enhancement.

➤ *Team Overmatch Program (TovM)*

Aims: Prevent unhealthy levels of stress that negatively affect cognitive performance, improving resilience and situational awareness, improving teamwork resilience and situational awareness in first aid through an integrated training approach.

➤ *Continuous Multi-faced Soldier Characterization for Adaptive Technologies (CMSCAT)*

Aims: Examination of external factors influencing the performance of soldiers. CCDC's ARL research and development program aims to understand how to develop analytical techniques to understand the impact of multiple contextual factors on predicting Soldier performance and to enable real-time adaptive technology performance improvement.

➤ *Restorative Sleep for Performance and Health (RSPH)*

Aims: The goal here is to implement a basic research program that will allow us to understand and predict the restorative benefits of sleep. In addition, to investigate how restorative sleep can help improve performance. The RPH programme was funded by the Military Operational Medicine Research Program (MOMRP).

➤ *Physiological Basis of Resilience*

Objectives: The physiological basis of resilience is the MRDC program led by WRAIR and USARIEM. The aim of the program is to improve the ability to bear mental burdens, to examine the possibilities of improving the ability to adapt to different (military) situations as well as life situations. The aim is also to identify measures that can predict the soldiers' ability to withstand stress and improve their physical, emotional and behavioral functioning.

➤ *A Sleep-on-Demand*

Objectives: The U.S. Army's Defense Institute of Chemical Medicine is conducting a joint basic research program with the U.S. Army laboratory to explore the neural circuits that regulate the sleep-wake transition, as well as to develop new technologies aimed at modifying or

regulating the activity of the nervous system to promote restful sleep or enhance wakefulness as desired. Electrical or chemical stimulation is often used for this, and the main goal is to modify the functioning of neuronal networks to achieve a therapeutic effect in the treatment of neuromedical or psychiatric conditions.

➤ *Noninvasive Neuromodulation for Warfighter Performance Enhancement*

Objectives: To improve combat performance, CCDC ARL and CCDC DAC have a basic and applied research programme to evaluate the effectiveness of safe neuromodulation technologies. The aim is to alter the rhythmic activity of the brain to influence behaviour and neuroplastic changes in sensory, motor and higher cognitive processes of the brain.

➤ *Formative Assessments of Junior Leader Competencies*

Objectives: An applied research programme at ARI aimed at developing critical competencies to support performance in the future operational environment by adopting a holistic assessment and feedback framework. It also aims to integrate cognitive, affective, socio-cultural and psycho physiological factors.

These topics focus on enhancing cognitive performance, but it is important to distinguish performance enhancement from optimization. Performance optimization in militaries often involves the application of technologies and techniques designed to maintain peak performance of individuals and teams despite environmental or task-related disturbances. Cognitive performance optimization strategies can achieve the same goals in the short and long term through precise management, combination and application. For soldiers, accuracy of shots and therefore effectiveness must be maintained under stress, pressure and uncertainty. This can be helped by making real-time location updates available to the personnel performing the tasks.

Performance enhancement is achieved by changing the power distribution, because it

is about increasing individual and team performance beyond maximum power. This definition is in line with the definition proposed by Bostrom & Sandberg (2009), who defined cognitive enhancement as “the amplification or extension of the basic capabilities of the mind by improving or extending internal or external information processing systems”. Cognitive development can help individuals to move towards a new personal performance maximum, thereby raising the standard of their future performance. It is essential, however, that optimization and improvement realize the performance advantages of individuals, but only in the latter case do the advantages exceed existing human capabilities. Another possible distinction between direct and indirect approaches to cognitive development is also apparent. We know two main forms of development methods. The essence of direct development is the incorporation of new techniques into learning (training) activities. The essence of these is practice, as a result of which a more economical and efficient knowledge processing can be created. The essence of indirect development is to directly develop the abilities that enable the development of more effective learning strategies. Accordingly, indirect development targets general intellectual abilities (attention, understanding, memory, problem solving).

The US military has a decades-long track record of research and development aimed directly at enhancing cognitive performance, seeking to improve processes and states such as alertness, situational awareness, decision making and emotion regulation. Let's look at three areas that need to be prioritized in the context of military research and training. These are the areas under investigation, for which we will also review the potential applications of AI later in this paper:

- targeted training technologies and methods;

- issues of transcranial electrical brain stimulation and reality enhancement;
- a review of related cognitive rehabilitation research.

During targeted training, soldiers learn how to use their weapons, control the parachute, program the radio, etc. There is already a large body of literature on the acquisition and practice of cognitive and procedural skills and the enhancement of learning in specific application areas that can be used in military training. Some of these are examples of direct approach methods:

- Rich multimedia learning experiences that increase the realism and vividness of learning materials, integrate more sensory modalities, build more comprehensive and flexible mental models, and offer more possible pathways for retrieval (Blankenbeckler, Graves & Wampler, 2014; Campbell, Cantrell, Generalao, Sawyer & Takitch, 2006).

- Validated teaching strategies to help consolidate and further develop memory, including retrieval practice, learning to master, split learning and introducing difficulties into learning to improve long-term memory (Brunyé et al, 2020; Brunyé, Smith, Horner & Thomas, 2018; Spain, Priest & Murphy, 2012, McDaniel & Einstein, 2006).

- Simulation-based training that emulates real training tasks and environments to increase realism, fidelity and user engagement in specific training experiences and facilitate knowledge transfer (Lackey, Salcedo, Matthews & Maxwell, 2014).

- Feedback methods (including biofeedback, neurofeedback and eye movement modelling) that encourage critical self-reflection and growth, error detection and correction, and deeper understanding (McDaniel & Einstein, 2006; Swets & Bjork, 1990).

The two techniques listed above use two or more electrodes placed on the

surface of the scalp to deliver low-intensity (direct or alternating) electrical currents to the cortical areas. The US Army's goal is to enhance memory, so the brain regions and mental processes targeted include the dorsolateral prefrontal cortex. The aforementioned CCDC SC MASTR-E programme includes an applied research project that will bring the best principles of learning and teaching science directly into the Army's training places.

Noninvasive brain stimulation (NIBS) aims to enhance brain function in a noninvasive way, a promising form of which is stimulating the brain with a weak magnetic or electric current. This method is gaining popularity in both clinical and commercial circles; many portable home devices are available on the commercial market for personal use. Military researchers are seeking to determine factors associated with enhanced cognitive and motor learning following transcranial direct current stimulation in healthy young adults. Understanding how participants respond to brain stimulation is critical to maximizing the effectiveness of stimulation and determining its potential as a performance-enhancing aid for mental tasks. Future developments in this study may also affect the ability of brain stimulation to act as a non-pharmacological alternative to treating cognitive decline. The US Army's main goal is to enhance memory, therefore focusing on this, it has already identified and investigated several NIBS methods for their performance-enhancing properties, especially transcranial direct current stimulation (tDCS) and transcranial alternating current stimulation (tACS). The two techniques listed use two or more electrodes placed on the surface of the scalp to administer low-intensity (direct or alternating) electric current to the cortical areas (Chase & Simon, 1973).

The US Army's research is aimed at improving navigation and spatial memory, enhancing face memory and boosting creative problem solving. These include

investigating ways to stimulate the right medial temporal lobe, the right spindle-shaped cortex and the left frontopolar region. Army research in this area started as basic research, but has been expanding in recent years and now includes specific programmes (such as the MASTR-E programme) with applied research projects. At this stage, it can be concluded that NIBS research holds great promise for improving many aspects of perception, cognition and emotion regulation that may be risk factors for soldiers in the course of their missions (O'Hanlon, 2019b).

The purpose of Reality Augmentation is to provide soldiers with relevant information to carry out their tasks. This inner experience or perception will not be a reflection of the outside world, but will only approximate it as much as the task to be performed requires. At the same time, the series of interacting events through which environmental stimuli are experienced can directly influence the actions of soldiers. Let's look at two examples of how this can be realized in military tasks.

Augmented reality systems aim to provide spatial information that directly supports location, orientation and route planning, as well as navigation. Augmented localization can be achieved by updating grid coordinates or mini-map markers in real time using graphical overlays. Improved orientation can be achieved by using "sneak-in" beacons to show the direction and distance of prominent landmarks and known friendly and enemy units, which can have the positive effect of reducing uncertainty and anxiety and increasing the accuracy and speed of decision making. Route planning for individuals and collaborating organizations can be further enhanced by providing interactive and three-dimensional terrain mapping.

Augmented reality can also be one of the "tools" that can help to improve threat detection, classification and the ability to successfully manage threats. New systems that have emerged can help to detect threats

effectively and can also alert the user to potential threats. Systems that are able to detect target characteristics and use machine vision and artificial intelligence to help classify the probability and potential magnitude of an emerging threat will play a key role. Real-time information about the environment can be used to mark the so-called centre of mass of targets. Augmented reality offers great opportunities for examining the connections between virtual and real environments. The goal is to be able to interact with the immediate environment and connect real and virtual objects.

3. Restoring military cognitive skills

Rehabilitation of cognitive skills involves therapeutic approaches that armies have invested heavily in investigating. Many years of research have examined ways of preventing mild and moderate traumatic brain injury (TBI) and ways of assessing and treating injuries that occur with both short- and long-term cognitive impairment. These include, for example, impaired (reduced) attention, memory, language and problem-solving skills.

In addition to the direct approach, the US military has also researched a number of indirect cognitive performance enhancement techniques. Indirect techniques generally make use of a wide range of cognitive and social-emotional skill development and interactive links between biological systems such as the gut, brain and peripheral nervous system. Here we can consider five broad categories of indirect enhancement:

- changes in dietary and nutritional habits;
- increasing resilience and strengthening teamwork;
- peripheral nerve stimulation;
- increasing the duration of different physical activities;
- and the elimination of sleep disorders.

As alertness, executive function, creative problem solving and emotion regulation are all very important factors for soldiers in the performance of their tasks, they are also influenced by nutritional and dietary interventions. This may involve, for example, short or long-term modifications of nutritional supplements or eating habits. Caffeine consumption is common among military personnel, and as a dietary supplement it has the potential to alter peripheral nervous system activity, so the effects of several stimulants, including caffeine, amphetamine, modafinil, nicotine and deprenyl on cognitive performance have been investigated. Several of these provide temporary arousal and alertness and can improve soldiers' cognitive performance, even when sleep is restricted. Caffeine has received particular attention because experiments have shown that it can improve visual alertness and aspects of executive control in soldiers with low or high alcohol consumption habits. The mechanism underlying the cognitive effects of caffeine is generally thought to be an increase in central and peripheral nervous system arousal through modulation of one or more neurotransmitter systems (e.g., adenosine, dopamine, and norepinephrine).

The US Army is leading a Defense Health Program initiative to manipulate soldiers' gut microbiome (the microbes that live in our guts) through polyphenol (antioxidant) nutrition and measure cognitive and physical performance at high altitude (in its simulated environment). The high-altitude environment is particularly challenging for soldier performance due to adverse effects on sleep, emotions, cognition and physical performance. The results of this research will be used to determine the gut microbiome and metabolite profiles that soldiers need to improve their performance in an operational environment. These profiles may guide the determination of required nutrition or supplementation as it may indirectly impact cognitive performance. Similarly, the

profiles may have implications for altering the composition of indigestible plant fibres and gut microbiota that stimulate the proliferation of the aforementioned gut bacteria, since live bacterial strains also have a significant impact on human cognitive performance.

Resilience is resilience in the psychological sense, the ability to cope with surprises, changes and unexpected obstacles. For soldiers, this cognitive and teamwork skills training involves the development of generic cognitive skills that enhance cognitive performance in situations of stress when soldiers are operating as part of a team.

According to CSF2 has Training Centers: “Comprehensive Soldier and Family Fitness (CSF2) is designed to build resilience and enhance performance of the Army Family – Soldiers, their Families, and Army Civilians. CSF2 does this by providing training and self-development tools so that members of the Army Family are better able to cope with adversity, perform better in stressful situations, and thrive in life”. Officially announced, Resilience Training involves the acquisition and practice of basic MRT skills. Accordingly, the primary goal of the training is to increase mental fitness, the ability to maintain optimal performance in stressful situations, which will also be necessary for effective leadership to achieve challenging goals. The US Army has implemented and tested mindfulness-based exercises, in particular Mindfulness-based Mind Fitness Training (MMFT) and Positive Emotional Resilience Training (P-ERT).

The US Army has launched a programme called Squad Overmatch, which aims to improve readiness and resilience by enabling soldiers and commanders to optimize the performance of end-operators in operational environments where uncertain and protracted task execution is predicted. Another key objective of the programme was to reduce the number of combat fatalities. This was to be achieved through training in performance and

resilience, which can enable effective tactical decision-making and casualty care under stressful conditions. They wanted to maximize the success of sub-units and reduce the number of preventable combat deaths. The programme is part of the Army's campaign to ensure that unhealthy stress does not affect performance. As part of the campaign, the Squad Overmatch program conducted a field trial to test the effectiveness of an innovative, integrated training approach to reduce stress during teamwork, resilience, situational awareness and tactical combat casualty care. Participants were trained in a traditional classroom environment (stand-up lecture), in a virtual environment using simulation-based team training (Virtual Battlespace III), and in live exercises (using actors and state-of-the-art simulation techniques).

Squad Overmatch is a training method that integrates classroom instruction, virtual training and live exercises to improve resilience, team development, battlefield medical skills, advanced situational awareness and after-action reviews (AAR). It stems from the Army's desire to improve individual and unit performance and help soldiers cope with the stress of combat and multiple deployments. In 2013, the Program Executive Office for Simulation Training and Instrumentation (PEO STRI), the Maneuver Center of Excellence and other organizations began work on Squad Overmatch. The programme is funded by the Defense Health Agency.

4. The challenges of military research

The aim of the US military and other services that share research with them is to gain a competitive advantage over potential adversaries. To do so, they are considering a number of cognitive development strategies. The focus of their research is on threat perception, improving the quality of decision-making, situational awareness and emotion regulation.

Research in the US military has already resulted in a number of methods to enhance cognitive performance. These results have already been demonstrated. Different approaches have been used to examine subsets of perceptual, cognitive, and affective processes, but each has experienced its own limitations and challenges, all of which have hindered execution. In addition to the US studies, it is also worth monitoring research from other militaries, as all of these may influence the effectiveness of development techniques and the quality of their application in a military context (Sha, Chen, Gao & Li, 2021; Deng & Yu, 2014).

First, it is not yet known what the trade-offs are between improving performance and potentially reducing other performance. This may be particularly true for brain stimulation approaches that alter the demands on metabolic resources in certain brain regions, potentially reducing their availability to other brain regions that we may rely on to perform tasks. This may be critical for mission tasks. This can be critical for mission tasks. When increasing individual level performance, trade-offs must also be made with respect to team level performance. For example, it is possible that improving the performance of individual team members due to increased expectations may unintentionally and negatively affect the overall performance of team members. Conversely, it is possible that previously low-performing team members may experience increased motivation from high-performing team members. Future research at the intersection of social and cognitive psychology needs to take into account the complex team dynamics that may arise when individualized development approaches are used in combination.

In the case of armies, one of the most important aspects is usually the cost of applying the development techniques, but an important aspect for society is also the extent of other short and long term costs to

soldiers' performance, health and well-being. If the long-term consequences of brain stimulation and some nutritional supplements have not been fully investigated during experimentation, and these may have a detrimental effect on health and general well-being, then their social importance is increased. Another important aspect of emerging development techniques is the state of regulation. Regulations are often controversial, for example for brain and peripheral nerve stimulation and drug supplementation. These contradictions limit the effectiveness of research and the potential widespread adoption of the techniques identified. During the programs, during teamwork trainings, development techniques were examined with field-specific tasks, but at the level of individual performance. This method has limited our understanding of how such techniques may advance group and more complex group tasks. In the case of soldiers, the requirements must be separated, which mean proficiency in a certain task, and this knowledge is not necessary for other tasks. Future military operations, on the other hand, clearly require complex cognitive processes. There is relatively little research on the development of general cognitive skills, and the results are inconclusive, even though targeted training methods have so far shown great effectiveness. Accordingly, this may be an area of future research for the military to explore further, and because of the group-level organization and complex, collective performance of military units, more emphasis should be placed on team-level development. They can be a valuable parameter in predicting the real-world results of development techniques used in a military environment (Li, Zhou & Chen, 2018; Prelipcean, Boscoianu & Moisesescu, 2019; Gao, Chen, Zhang & Gao, 2019).

The research results so far show that generalization cannot lead to results, because the results cannot be applied to all situations and for all people. In addition to

genuine performance improvement, the importance of measuring peak performance should be emphasized, because this will go beyond the human cognitive ability aspect and thus provide a basis for comparison. At the same time, without such measurements, it would be difficult to ensure the effectiveness of development programmes, and therefore difficult to distinguish between optimization and further development, which would encourage further research. In selecting development techniques, we may face a number of challenges that in development techniques to use in training and operations, there are a number of challenges that guide and constrain the design and application of tools. Among the various challenges are the requirements for the appropriate use of the tools and the normatives for training tasks associated with maintenance tasks. Network requirements for the operation of battlefield assets are another challenge that needs to be addressed. Among the battlefield assets, particular attention should be given to wearable and portable assets, as well as the associated hardware and software. Taking into account the challenges and opportunities of emerging technologies and techniques, research can be pursued in several directions (Chuang & Cheng, 2022)

5. Conclusions

The US military is paying close attention to research into ways to enhance cognitive performance. Already, years of work have included the incorporation of

modern technologies that have led to significant advances in medicine, nutrition, education, and sleep studies. Artificial intelligence has also been used as a new tool in this research. Research results so far have shown that it is possible to optimize performance, so it is worth continuing the work. The current research focuses on the question of whether the new technologies used, in particular artificial intelligence, can help soldiers to maintain high levels of performance in times of stress, fatigue and sleep deprivation.

Of course, a number of drugs are already available that are effective in reducing the negative effects on cognitive performance. To improve performance, we can use AI and continuous research to try to measure the peak performance of individuals and teams and then design improvement strategies that go beyond the new benchmark. Multidisciplinary disciplines can exploit future-oriented techniques in their research, taking advantage of advances in artificial intelligence and biomedical engineering. In these areas, researchers have made significant advances in human performance enhancement research, demonstrating the validity of these research directions. The results of this research could pave the way for increasingly accepted, reliable and effective methods of cognitive enhancement. They can help soldiers gain a competitive advantage over their opponents by accelerating situational awareness and improving the quality of decision-making under stress.

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