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Beyond Cognitive Screening: Toward a Paradigm of Neurocognitive Health, Operational Protection and Enablement of Military Personnel

James Giordano*

Center for Strategic Deterrence and Studies of Weapons of Mass Destruction, Institute for National Strategic Studies, National Defense University, Washington, DC, USA

***Corresponding Author**: James Giordano, Center for Strategic Deterrence and Studies of Weapons of Mass Destruction, Institute for National Strategic Studies, National Defense University, Washington, DC, USA.

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Abstract

The United States Department of War (DoW) transition from the Automated Neuropsychological Assessment Metrics (ANAM) to a next-generation cognitive assessment capability is an important advance in military brain health and operational readiness. However, contemporary operational environments demand a more comprehensive approach than behavioral cognitive testing alone. Advances in neuroscience, neurotechnology, multimodal neuroimaging, electrophysiology, biomarker science, and artificial intelligence (AI) now enable far more precise characterization of the structural and functional neural systems that subserve cognitive performance, resilience, vulnerability, and recovery.

This essay posits that these capabilities should be constituent to a new enterprise of precision neurocognitive health; and proposes a paradigmatic approach, NeuroHOPE (Neurocognitive Health, Operational Protection, and Enablement) to establish individualized multidimensional neurocognitive baselines for service members, employ longitudinal monitoring throughout military service, and integrate evidence-based interventions to preserve and enhance cognitive readiness. NeuroHOPE combines structural and functional neuroimaging, quantitative electrophysiology, wearable neurophysiologic monitoring, digital cognitive phenotyping, validated biomarkers, and AI-enabled data integration to facilitate earlier detection of subtle neurologic change, improve diagnostic precision, personalize intervention strategies, and optimize operational performance while supporting informed return-to-duty and veterans' disability determinations.

Recognizing the unique sensitivity of neurobiological information, the necessity of rigorous neuroethical oversight and governance is advocated and recommendations are presented to guide phased implementation of NeuroHOPE paradigm within a DoW-wide Precision Neurocognitive Readiness Program toward strengthening force protection, enhancing mission effectiveness, and sustaining strategic advantage in an era in which cognitive superiority increasingly defines military success.

***Keywords**: Neurocognitive Testing; Military Medicine; Neurotechnology; Optimization; Neuroethics*

Introduction: Advancing Past ANAM

The recent announcement that the United States' Department of War (DoW) will replace the long-serving Automated Neuropsychological Assessment Metrics (ANAM) with a next-generation cognitive monitoring capability is a timely and commendable advance in military brain health and operational readiness. The stated goals of modernizing an enterprise that has relied upon legacy technologies so as to detect cognitive changes earlier, and provide actionable information to clinicians and commanders are entirely appropriate to the realities of contemporary warfare. And the DoW's recognition that cognitive performance constitutes a fundamental component of combat effectiveness as well as a medical concern, reflects an equally important advance [1].

But while this modernization is necessary and overdue, it should not be regarded as an end point of military cognitive assessment. Rather, it should be viewed as an important first step toward a far more comprehensive paradigm of precision neurocognitive health, operational protection and enablement. The character of warfare has changed; success on the current and near-future battlefield increasingly depends upon rapid processing of multivariate information, adaptive decision-making, resilience in conditions of uncertainty, and sustained cognitive performance in highly contested environments. These capabilities are neither adequately characterized nor protected by computerized neuropsychological testing alone. Modern neuroscience and technology (neuroS/T) now afford substantially more granular means of understanding the structural and functional architecture that subserves neurocognitive performance, resilience, vulnerability, and recovery.

Neurodata beyond behavioral assessments

Accordingly, the DoW should expand its concept of cognitive monitoring from behavioral assessment to multidimensional neurocognitive characterization. Historically, neuropsychological testing has served as a practical surrogate for brain function [2]. Such assessments evaluate observable performance on tests of reaction time, attention, working memory, executive function, and processing speed. Of course, these remain valuable measures, particularly because they are inexpensive, portable, repeatable, and operationally feasible. However, they remain indirect, as behavioral performance represents only an external expression of underlying neural systems' structure, connectivity, metabolism, electrophysiology [3]; and adaptive plasticity that may change long before behavioral deficits become clinically apparent [4].

Conversely, subtle alterations within neural networks may precede measurable changes on conventional cognitive testing by months or years. Current advances in neuroS/T (e.g. functional magnetic resonance imaging [fMRI]; diffusion tensor imaging [DTI]; magnetoencephalography [MEG]; genetic testing; biomarker evaluation) now permit increasingly precise evaluation of these underlying biological correlates. Individually, each modality offers only partial insight, but collectively they provide a remarkably comprehensive portrait of neurocognitive function, health and readiness. Moreover, recent advances in big data analytics, machine learning, large-scale data integration, and AI now permit diverse neuroS/T-obtained data to be synthesized into individualized neurocognitive profiles that greatly exceed the interpretive power of any single assessment modality ([5,6]; see also, below). The resulting precision in neurocognitive assessment has immediate operational relevance.

Perhaps its greatest value lies in establishing individualized baseline characterization prior to operational exposures. The military has long appreciated the importance of physiological baselines. Baseline hearing tests, pulmonary function testing, visual acuity assessments, and physical fitness evaluations all permit determinations of qualification for duties and whether and to what extent subsequent changes reflect incurred injury or preexisting variation. Brain health deserves no less. Indeed, because it is now recognized that every brain is unique, individualized baseline characterization becomes even more essential [7].

Comprehensive pre-service and pre-deployment baseline assessments incorporating structural and functional imaging of selected measures, electrophysiology, cognitive testing, and validated biological markers would permit clinicians to determine not merely that cognitive performance has changed following exposure to various weaponry (including biological effects of directed energy devices [8,9]), concussion, repetitive sub-concussive injury, sleep deprivation, environmental stressors, or toxic exposure, but precisely which and how affected neural systems have changed. Such individualized comparisons would substantially improve diagnostic sensitivity, reduce uncertainty surrounding mild brain injury, facilitate earlier intervention, and enable far more accurate prognostication regarding return-to-duty or presumptive risk and veterans' benefits decisions.

Equally important, these same baseline datasets could become foundational for optimizing warfighter neurocognitive function. The DoW increasingly recognizes that cognitive performance should be managed with the same rigor as physical performance [10]. Yet, optimization requires insight to and evaluation of individual neurocognitive variation. To be sure, some personnel possess exceptional attentional endurance; others demonstrate superior adaptive flexibility, emotional regulation, spatial reasoning, or rapid learning. Understanding the neurologic bases of these differences could permit more individualized approaches to training, occupational assignment, human-machine teaming, sleep management, nutritional interventions, stress inoculation, and pharmacologic and/or neurotechnological supplementation when and where appropriate.

These approaches need not imply enhancement beyond normal human capability [11]. Realistically, they support the more modest, and arguably operationally important goal of enabling every service member to perform consistently at the highest level permitted by his or her unique neurobiology. Such use of neuroS/T thus enables precision readiness. Nevertheless, any proposal advocating comprehensive neurocognitive characterization and possible enablement must acknowledge equally significant ethical, legal, and policy challenges [12].

The delicacy and demands of neurodata

As we and others have previously noted, neurobiological information is uniquely delicate [13,14]. Unlike many conventional medical data, neural information may reveal aspects of cognition, emotional regulation, behavioral tendencies, vulnerability to stress, recovery potential, or future neurological risk. Whether or not such inferences ultimately prove valid, the possibility alone generates profound ethical obligations regarding collection, interpretation, storage, ownership, access, and use. Service members must possess confidence that such information will not become an instrument of discrimination, career limitation, administrative action, or unwarranted surveillance. Accordingly, robust governance mechanisms become indispensable.

Our ongoing work has defined five foundational precepts important for maintaining the security and probity of neurodata [15]. First, neurocognitive data must be protected under rigorous cybersecurity standards equivalent to those governing other highly sensitive medical information. Second, clear custodianship policies must specify precisely who owns these data, who may access them, for what purposes, and under what circumstances secondary uses may occur. Third, strict provenance standards must ensure traceability of data acquisition, analytical methods, algorithmic modifications, and interpretive outputs to preserve scientific integrity and legal accountability. Fourth, AI systems employed in neurocognitive interpretation must remain transparent, auditable, clinically validated, and continuously evaluated for algorithmic bias. Finally, meaningful human oversight of any AI systems employed must remain central to all consequential decisions affecting medical care, operational assignment, promotion, or retention [16,17]. To this point, neuroscience should inform judgment, not replace it.

Indeed, preserving trust between the institution and individual military personnel may ultimately prove as important as the technological sophistication of the assessment itself. The future of military cognitive readiness will not be secured solely through better testing. It will be achieved through the thoughtful integration of neuroscience, AI, precision medicine, operational psychology, systems biology, military ethics, and responsible governance into a coherent enterprise that protects the brain while simultaneously enhancing mission effectiveness.

NeuroHOPE: An integrative paradigm for neurocognitive health, operational protection, and enablement

While military medicine has achieved remarkable success in protecting and restoring physical health, it is becoming increasingly evident that maintaining optimal neurocognitive function should be regarded as a strategic priority rather than merely a clinical concern. To this end, a comprehensive paradigm, NeuroHOPE (Neurocognitive Health, Operational Protection, and Enablement) is proposed that integrates state-of-the-art neuroscience, neurotechnology, computational analytics, and precision medicine to assess, monitor, protect, and optimize neurocognitive performance of military personnel across the continuum of their service. The central premise of NeuroHOPE is that neurocognitive health represents the dynamic capacity of an individual to perceive, process, adapt, recover, and learn within operational environments that impose substantial physiologic, psychologic, and informational demands. This perspective shifts military neurocognitive health from a reactive paradigm focused on diagnosis and rehabilitation toward a proactive model emphasizing prediction, prevention, protection, and performance enablement.

The NeuroHOPE paradigm would establish individualized multidimensional neurocognitive baselines for every service member entering operational training. Such evaluations would incorporate structural and functional neuroimaging, electrophysiologic assessment using high-density EEG, quantitative eye-tracking, autonomic physiologic measures, vestibular and sensorimotor testing, digital cognitive phenotyping, sleep and circadian analyses, and validated behavioral performance metrics. When integrated with genetic, epigenetic, metabolic, inflammatory, and other biomarker profiles, these data would create an individualized neurobiological "fingerprint" against which future changes could be objectively compared.

Importantly, the value of these baseline assessments extends beyond diagnosis of traumatic brain injury. Contemporary neuroscience demonstrates that numerous operational stressors (e.g. sleep deprivation, prolonged cognitive workload, blast exposure, hypoxia, environmental toxins, infectious disease, emotional stress, and repeated subconcussive insults) produce measurable alterations in brain network function well before overt clinical symptoms become apparent [18]. By employing longitudinal monitoring throughout a service member's career, NeuroHOPE could identify subtle deviations from baseline that signal emerging vulnerability, thereby enabling early intervention before functional degradation adversely affects mission performance or long-term health.

The monitoring component of NeuroHOPE would leverage emerging wearable and portable neurotechnologies capable of acquiring physiologic and neurophysiologic data during both training and operational activities. Advances in dry-electrode EEG systems, functional near-infrared spectroscopy, wearable physiologic sensors, ocular tracking systems, and multimodal biometric platforms increasingly permit real-time assessment of fatigue, cognitive workload, situational awareness, stress responses, and recovery trajectories. These technologies, integrated through secure AI-enabled analytic platforms, could provide objective measures of individual and unit neurocognitive readiness while preserving appropriate protections for medical confidentiality and individual privacy.

Beyond assessment and monitoring, NeuroHOPE emphasizes intervention. Importantly, intervention should be viewed as a palette of evidence-based approaches that can be used to promote resilience, facilitate recovery, and enhance operational capability. These interventions may include individualized sleep optimization protocols, nutritional strategies supporting neuroplasticity and metabolic resilience, precision physical conditioning, cognitive training, stress inoculation, mindfulness-based performance enhancement, EEG-guided neurofeedback, non-invasive neuromodulation where clinically appropriate, virtual and mixed-reality simulation for cognitive skill acquisition, and adaptive human-machine interfaces capable of reducing excessive cognitive burden during complex operations.

And to reiterate, AI would be a critical enabling technology within the NeuroHOPE paradigm, given that the volume and diversity of multimodal physiologic, behavioral, neuroimaging, and operational data exceed the analytic capacity of conventional approaches. Indeed, machine learning algorithms capable of identifying complex multidimensional patterns may reveal early indicators of cognitive decline, predict injury susceptibility, personalize intervention strategies, and continuously refine models of operational readiness (see also, above). Thus, AI would serve as a decision-support tool that augments military medical expertise by integrating diverse datasets into clinically actionable information.

NeuroHOPE offers a scientifically grounded framework for integrating contemporary neuroscience into military medicine in a manner that is proactive, personalized, operationally relevant, and ethically responsible. By combining advanced assessment, continuous monitoring, precision intervention, and rigorous governance, NeuroHOPE has the potential to preserve neurocognitive health, reduce operational risk, accelerate recovery from injury, and optimize personnel performance across the full spectrum of military service. To be sure, implementation of NeuroHOPE demands careful attention to ethical, legal, and policy considerations. As we have previously noted, and reinforce here, compliance with (and iterative informing of) regnant signatory treaties and conventions (e.g. the Biological and Toxins Weapons Convention; BTWC), guidelines, policies and international laws, as well as rigorous standards governing informed consent, data provenance, cybersecurity, confidentiality, authorized access, algorithmic transparency, and protection against discriminatory use must accompany any deployment of these technologies [19,20].

Conclusion and Recommendations

But perhaps the greatest perceived strategic value of the proposed NeuroHOPE paradigm would be a transformation of military medicine from episodic clinical care to continuous neurocognitive stewardship. This approach reflects cognizance of optimal personnel performance being dependent upon both physical readiness as well as the integrity of neural systems responsible for physical expression activity, and the cognitive processes of judgment, adaptability, learning, emotional regulation, and decision-making under conditions of uncertainty and extreme stress. In this regard, neurocognitive health would become an essential component of force protection and operational capability and deterrence.

Toward implementing and maintaining such a paradigm, the following recommendations are offered:

1. The DoW should establish a precision neurocognitive readiness program as a phased, enterprise-wide initiative that augments computerized cognitive testing with multimodal neuroimaging, quantitative electrophysiology, validated biomarkers, and AI-enabled analytics to establish individualized neurocognitive baselines for all deploying personnel and high-risk occupational specialties.
2. A secure military neurodata infrastructure should be developed that establishes a protected, federated repository capable of integrating neuroimaging, physiological, cognitive, operational, and exposure data under rigorous standards for cybersecurity, custodianship, provenance, interoperability, and controlled access; thereby enabling longitudinal assessment while safeguarding individual privacy.
3. AI-assisted longitudinal brain health monitoring program(s) should be implemented. Validated machine-learning tools should be employed to compare each service member's post-exposure neurobiological profile against his or her own baseline, allowing earlier detection of subtle injury, individualized clinical intervention, and more informed return-to-duty or post-service disability benefits' determinations.
4. Neurocognitive optimization should be integrated within military human performance programs. Baseline neurobiological characterization should be used to personalize evidence-based interventions (viz. -sleep optimization, stress resilience training, neurofeedback, cognitive training, nutritional strategies, and human-machine interface technologies) to maximize operational performance while preserving long-term neurological health.

5. A DoW-wide neuroethics and neurogovernance framework should be developed to support and sustain comprehensive policy governing informed consent where appropriate, privacy protections, algorithmic transparency, data stewardship, secondary use, operational decision-making, and independent ethical oversight to ensure that advances in military neuroscience strengthen both readiness and the trust of those who serve.

If implemented judiciously, with appropriate scientific rigor, ethical prudence, and operational realism, such an enterprise could transform how the United States military and its allies detect injury, preserve brain health, accelerate recovery, optimize human performance, and ultimately sustain strategic advantage in an era where cognitive superiority increasingly determines operational success.

Disclaimer

The views and opinions expressed in this essay are those of the author and do not necessarily reflect those of the United States government, the Department of War or the National Defense University.

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