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Cognitive Performance Enhancement for Multi-domain Operations

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ABSTRACT: Despite its desire to achieve cognitive dominance for multi-domain operations, the Army has yet to develop fully and adopt the concept of cognitive performance enhancement. This article provides a comprehensive assessment of the Army's efforts in this area, explores increasing demands on soldier cognition, and compares the Army's current approach to its adversaries. Its conclusions will help US military and policy practitioners establish the culture and behaviors that promote cognitive dominance and success across multiple domains.

Keywords: cognitive performance, resilience, neuroethics, human performance, information overload

Cognitive capability is the critical variable supporting all soldier performance: physical, mental, and emotional. US Army doctrine recognizes the importance of cognitive dominance, or gaining intellectual advantage over the enemy. It even features prominently in several recent publications, including the *2019 Army Modernization Strategy (AMS)* and the *U.S. Army in Multi-Domain Operations (MDO) 2028* concept.[1] Despite advances in cognitive science and recognition of the importance of cognitive overmatch in multi-domain operations, however, the US Army has not fully embraced the concept of cognitive performance optimization. The US National Institutes of Health have invested over $53.5 billion in brain research in the past decade, but soldiers and leaders train and operate inside an "always on" culture of multitasking and connectivity with habits ultimately degradative of cognitive performance.[2] Both at home station and when deployed, leaders attempt to filter dozens of streams of information and make rapid decisions while operating on inadequate sleep and a limited understanding of the principles of cognitive performance optimization.[3]

1. Department of the Army (DA), *2019 Army Modernization Strategy (AMS): Investing in the Future* (Washington, DC: Government Publishing Office, 2019), 8, accessed October 21, 2020, https://www.army.mil/e2/downloads/rv7/2019_army_modernization_strategy_final.pdf; and Department of the Army (DA), TRADOC Pamphlet 525-3-1, *The U.S. Army in Multi-Domain Operations (MDO) 2028* (Washington, DC: Government Publishing Office, November 2018), C–10, https://adminpubs.tradoc.army.mil/pamphlets/TP525-3-1.pdf.

2. National Institute of Health, "Estimates of Funding for Various Research, Condition, and Disease Categories (RCDC)," NIH RePORT research Portfolio Online Reporting Tools (website), last modified February 24, 2020, https://report.nih.gov/funding/categorical-spending#/.

3. Walter Reed Army Institute of Research, "WRAIR Investigator's Dispatch: Sleep Dispatch: Fighting Soldier Fatigue & Enhancing Cognitive Dominance" (Fort Detrick, MD: Walter Reed Army Institute of Research, June 2019), 3, https://www.wrair.army.mil/sites/default/files/2019-06/Behavioral_Health_and_Sleep.pdf; and Andrew C. Steadman, *Applying Neuroscience to Enhance Tactical Leader Cognitive Performance in Combat*, (master's thesis, US Army Command and General Staff College, 2011), 6, https://apps.dtic.mil/sti/pdfs/ADA556552.pdf.

Meanwhile, China and Russia have pursued biotechnical, neuroscientific, and artificial intelligence (AI) solutions to enhance human cognition and gain an asymmetric operational advantage over the United States and its allies.[4] Unfettered by the ethical norms of Western society, China and Russia actively leverage dual-use civilian and military research to achieve this end.[5] Both nations see the mind as the main battlespace in future warfare and are taking steps to dominate there.[6]

To meet this challenge, the US Army must remain aligned with Department of Defense cognitive performance research and development efforts. Science alone, however, will not be enough. The Army must also evolve its culture to recognize the importance of ethical, science-based methods to ensure cognitive dominance in ways that drive competition and innovation across the force. A deliberate approach to behavior modification rooted in education, training, and technology is needed to replace outdated cognitive performance myths that ultimately degrade cognitive function through multitasking, sleep deprivation, and information overload. Otherwise, our adversaries may find the asymmetric advantage they need to dominate the US Joint force.

Multi-domain Operations and the Cognitive Domain

Cognitive performance is the ability to observe, orient, decide, and act to produce the best possible outcome.[7] Cognitive skill has always been important to success on the battlefield and plays a critical role in deciding battles and campaigns. The future will offer similar opportunities but with greater complexity, fog, and friction as the battlefield expands into space and cyberspace. The *2019 AMS* addresses this evolving environment and introduces the concept of multi-domain operations.[8] The *2019 AMS* outlines how the MDO concept differs from previous operational concepts and requires higher levels of cognitive performance of its practitioners.

The MDO concept presents a cognitive challenge as it requires leaders to recognize and exploit fleeting opportunities to achieve cross-domain convergence of effects

4. Elsa B. Kania, "Minds at War: China's Pursuit of Military Advantage through Cognitive Science and Biotechnology," *Prism* 8, no. 3 (2019): 84, https://ndupress.ndu.edu/Portals/68/Documents/prism/prism_8-3/prism_8-3_Kania_82-101.pdf; and Lindsay Gorman "A Silicon Curtain Is Descending: Technological Perils of the Next 30 Years," in *Reassessing 1989*, edited by Thomas Kleine-Brockhoff (German Marshall Fund of the United States, 2019), 74, http://www.jstor.org/stable/resrep21249.16.

5. Guillermo Palchik, Celeste Chen, and James Giordano, "Monkey Business? Development, Influence, and Ethics of Potentially Dual-Use Brain Science on the World Stage," *Neuroethics* 11 (February 11, 2017): 112; and Royal Society, *Brain Waves Module 3*, technical report, RS Policy Document 06/11 (London: Royal Society Science Policy Centre, 2012) 7–9.

6. Kania, "Minds at War," 85; and Jānis Bērziņš, "The West Is Russia's Main Adversary, and the Answer Is New Generation Warfare," *Sicherheit und Frieden* (S+F) / Security and Peace 34, no. 3 (2016): 173, https://www.jstor.org/stable/26428998.

7. John R. Boyd, *A Discourse on Winning and Losing*, ed. Grant T. Hammond (Maxwell Air Force Base, AL: Air University Press, 2018), 384, https://www.airuniversity.af.edu/Portals/10/AUPress/Books/B_0151_Boyd_Discourse_Winning_Losing.PDF.

8. DA, *2019 AMS*, 4–5.

against advanced adversary capabilities in a complex operational environment.[9] To win in multi-domain operations, the US Army fields increasingly sophisticated systems along six modernization priorities that cut across all domains.[10] Not only do these advanced systems require higher intelligence and technical skill to operate and maintain, but when combined with improved digital communication and networking capabilities, leaders can also access more real-time data than ever before. Finally, the *MDO 2028* concept and the "Army People Strategy" place the American soldier at the center of the multi-domain operations concept.[11] Indeed, "[t]he Army's greatest strength and most important weapon system," soldiers will operate at the nexus of a myriad of real-time data and information sources and face increasing pressure to multitask, prioritize, assess, decide, and act as opportunities and threats arise. [12]

It is tempting to dismiss these challenges on the promise of advances in AI, human-machine interfaces, and other technologies.[13] Many of these capabilities remain hypothetical, however, even as the cognitive demands on soldiers continue to rise. Even when they become available, AI and other technologies will complement human decision making, but the human brain will likely remain the critical node in the near term. As such, achieving cognitive dominance starts with developing an understanding of the basic capabilities and limitations of the human brain. Cognitive scientists such as David Rock insist understanding brain function is one of the best ways to improve cognitive performance.[14] The concepts of optimal arousal, multitasking, cognitive endurance, and decision quality offer a framework for understanding and provide opportunities for performance enhancement.

Optimal Arousal

Levels of emotional arousal directly impact cognitive performance. The Yerkes-Dodson Law, first hypothesized in 1908, provides a basic model for this phenomenon and describes a sweet spot of cognitive arousal associated with peak performance.[15] The right level of arousal, or stress, causes the brain to release just the right mix of neurochemicals to generate the alertness and focus required for optimal performance.[16] Good coaches recognize how arousal levels impact performance

9. DA, *MDO 2028*, iii.
10. DA, *2019 AMS*, 6.
11. DA, *MDO 2028*, iv; and Department of the Army, "The Army People Strategy," (October 2019) 3, https://www.army.mil/e2/downloads/rv7/the_army_people_strategy_2019_10_11_signed_final.pdf.
12. Department of the Army, "The Army People Strategy," (October 2019) 3, https://www.army.mil/e2/downloads/rv7/the_army_people_strategy_2019_10_11_signed_final.pdf.
13. Paul Scharre and Michael C. Horowitz, "Research Report: The Artificial Intelligence Revolution," from *ARTIFICIAL INTELLIGENCE: What Every Policymaker Needs to Know*, report (Washington, DC: Center for a New American Security, 2018), 3–4, http://www.jstor.org/stable/resrep20447.4.
14. David Rock, *Your Brain at Work, Revised and Updated: Strategies for Overcoming Distraction, Regaining Focus, and Working Smarter All Day Long* (New York: Harper Business, 2020), 1.
15. Rock, *Your Brain at Work*, 62; and Diane Pomeroy, *The Impact of Stressors on Military Performance* (Fishermans Bend, Australia: Land Division, DSTO Defence Science and Technology Organisation, December 2013), 6–7.
16. Rock, *Your Brain at Work*, 64.

and succeed in calming or pumping up a team as needed during competition.[17] Too little leaves us flat, and too much creates counterproductive levels of stress, anxiety, or disengagement.[18] Army leaders may be familiar with this phenomenon in combat situations where physical threats incite powerful reactions, but similar states can occur under conditions of work stress and information overload.[19]

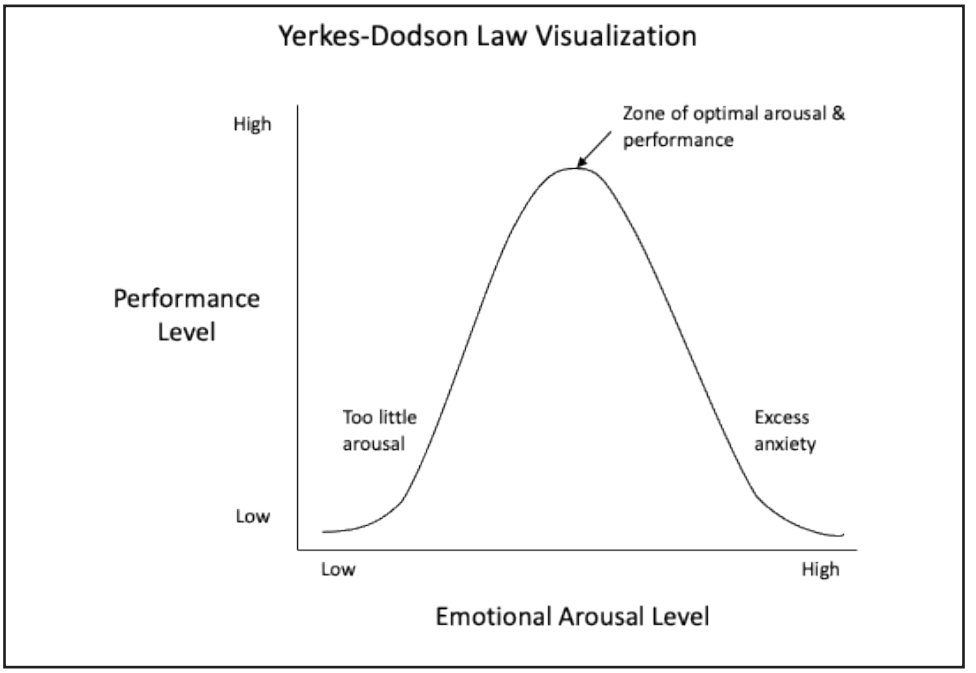

Figure 1. Yerkes-Dodson Law visualization

Although challenging to limit stress and anxiety in combat, monitoring and managing soldier emotional arousal levels can provide immediate opportunities for cognitive performance enhancement. One novel solution described by the UK Royal Society suggests military and law enforcement use cognitive overload monitoring systems to alert individuals when they show signs of cognitive overload. This awareness would allow users to consciously alter their states of emotional arousal and behavior to focus on the most critical problems.[20] Similarly, the Monitoring and Assessing Soldier Tactical Readiness and Effectiveness pilot research study conducted by the US Army Combat Capabilities Development Command Soldier Center focused on the optimization of individual soldier and small-unit perception, cognition, and interaction through innovative science and technology.

17. Phil Stieg and Marvin Chung, "Information Overload," April 3, 2020, *This Is Your Brain with Dr. Phil Stieg*, podcast, 5:50, https://thisisyourbrainwithdrphilstieg.libsyn.com/information-overload.
18. Rock, *Your Brain at Work*, 62.
19. Mark Goulston, Just *Listen: Discover the Secret to Getting through to Absolutely Anyone*, (New York: American Management Association, 2010) 16; and Rock, *Your Brain at Work*, 67.
20. Royal Society, *Brain Waves*, 38–39.

By analyzing data collected through body-worn and laboratory sensors during sustained training, the study identified opportunities for additional research that could help soldiers and leaders identify, predict, and sustain optimal arousal and tactical performance levels affecting decision quality, marksmanship accuracy, and attentional control.[21]

Multitasking

Military leaders are expected to develop an ability to juggle multiple balls—to respond immediately to texts, chats, and e-mails and to maintain situational awareness while solving problems in a rapidly changing environment. Unfortunately, the very tools Army leaders use and the methods of their use thicken the "fog of war" in combat as well as in garrison. Despite the demands of an increasingly connected society, science shows there are limitations to the number and complexity of operations the brain can process at any given time. Focusing our attention requires allocation of neural resources in the prefrontal cortex that prevents the brain from effectively focusing on two things at once.[22] When multitasking, our brains are instead forced to transition rapidly from topic to topic. Switching between tasks requires high amounts of metabolic resources such as oxygenated glucose; once depleted, both cognitive and physical performance decline.[23] Multitasking also produces the stress hormone cortisol and affects both adrenaline and dopamine levels in ways that scramble our thinking.[24] The profundity of the impact of multitasking has convinced some researchers a constant string of interruptions—through text, email, radio traffic, and chat windows—may produce an effect similar to temporarily lowering your IQ.[25]

Additionally, research demonstrates that multitasking increases decision-making risk. A 2009 Stanford University study claims heavy media multitaskers suffer degraded memory, learning, and cognitive function. The study compared the cognitive abilities of groups identified as heavy and light multitaskers.[26] While other factors could contribute to this degradation, the study suggests habitual multitasking may ironically impair

21. Erika Hussey and John Ramsay, *Monitoring and Assessing Soldier Tactical Readiness and Effectiveness (MASTR-E): Identifying the Readiness States and Traits of Tactical Mastery* (Natick, MA: US Army Combat Capabilities Development Command Soldier Center, April 27, 2020), 5.

22. Daniel Levitin, *The Organized Mind: Thinking Straight in the Age of Information Overload* (New York: Dutton, 2014), 39.

23. Levitin, *The Organized Mind*, 98.

24. Christine Rosen, "The Myth of Multitasking: How Intentional Self-Distraction Hurts Us," *The New Atlantis*, no. 20 (Spring 2008): 107; and Levitin, The Organized Mind, 96–98.

25. Rosen, "Multitasking," 36.

26. Eyal Ophir, Clifford Nass, and Anthony D. Wagner and Michael I. Posner, ed., "Cognitive Control in Media Multitaskers," *Proceedings of the National Academy of Sciences* 106, no. 37 (September 15, 2009): 15,583–87.

an individual's ability to accomplish occasional multitasking.[27] Consider, for example, a driver in an unfamiliar part of town holding a conversation with a passenger while listening to the radio. After a missed turn, the driver instinctively pauses the conversation and turns down the radio to focus on correcting course. The driver's actions show an intuitive awareness of the challenges of doing two things at once.[28] By choosing to multitask we accept degraded performance, formally known as "dual task interference" or the "psychological refractory effect."[29]

As part of an Army-wide brain science education initiative, early career education could provide a meaningful first step toward reducing the culture of multitasking, distraction, frequent interruption, and information overload. Techniques such as meditation, deliberate reflection, metacognition, mindfulness, and mindful awareness offer accessible, low-cost ways to build better cognitive habits across the force by enhancing focus and performance to meet training and mission requirements.[30]

Cognitive Endurance

Army brain science education could also help leaders understand the cumulative toll of decision making and attentional filtering on cognitive performance. The brain has limited resources available for data processing, and actions such as making a decision, resisting an impulse, or ignoring a distraction drain our cognitive energy over time.[31] Environments filled with trivial choices and distracting information exhaust our minds and dull our cognitive abilities, as the brain does not distinguish or prioritize decisions by level of importance.[32] Said differently, our decision-making ability is subject to the limits of cognitive endurance and degrades over time.

Despite an innate awareness of the limits of cognitive endurance, many military leaders do not structure their schedules and battle rhythms to account for this. For example, commanders who hold "night court" nonjudicial punishment hearings at the end of the duty day may make important decisions when the cumulative effects of daily decision making have rendered their cognitive abilities problematic and unreliable. Conversely, leaders may spend their most productive hours answering emails or executing

27. Ophir et al., "Cognitive Control," 15,585.
28. Levitin, *The Organized Mind*, 11.
29. Harold Pashler, "Attentional Limitations in Doing Two Tasks at the Same Time," *Current Directions in Psychological Science* 1, no. 2 (April 1992): 45.
30. Headquarters, Department of the Army (HQDA), Army Field Manual (FM) 7-22, *Holistic Health and Fitness* (Washington, DC: Government Publishing Office, 2020), 13-3.
31. Rock, *Your Brain at Work*, 8–9.
32. Levitin, *The Organized Mind*, 6–7.

low-level tasks instead of maximizing their cognitive resources to accomplish complex tasks and decision making. These basic examples illustrate why the Army must include time management education and training in its cognitive dominance efforts.

Decision Quality

Even while considering the limits of cognitive endurance our brains are often inundated with information that must be synthesized before being acted upon. Studies of optimal complexity theory indicate there is an optimal number of factors to be considered when making a decision and that too few or too many degrade performance.[33] Just like studies on computers, these studies reveal the limits on the working memory of humans. We struggle to hold more than three to five pieces of knowledge in mind while synthesizing understanding.[34] Furthermore, attempting to consider more than 10 factors significantly degrades performance.[35] Understanding this phenomenon could help facilitate better decisions, particularly when time is of the essence.

Many believe more inputs will lead to optimal decision making. In decision-making experiments where subjects requested more information after exceeding the optimal level of complexity, the subjects' performance degraded through information overload.[36] This trend is of particular concern to the military, where information supremacy in Iraq and Afghanistan now conditions senior leaders to expect an abundance of information to support their decision making. Information addiction may delay commanders waiting for more information that, ironically, would degrade the quality of their decisions.[37]

The military recognizes this challenge and is leveraging AI to develop improved information-filtering and decision-support algorithms to enable leaders to make better, faster decisions.[38] While promising, these efforts will be limited in the near future and will not fully alleviate the cognitive challenges associated with modern warfare. Once again, education on the

33. Levitin, *The Organized Mind*, 308.
34. Nelson Cowan, "The Magical Mystery Four: How Is Working Memory Capacity Limited, and Why?," *Current Directions in Psychological Science* 19, no. 1 (2010): 56.
35. Naresh K. Malhotra, "Information Load and Consumer Decision Making," *Journal of Consumer Research* 8, no. 4 (March 1982): 427.
36. Levitin, *The Organized Mind*, 310.
37. Alexander Kott, *Battle of Cognition: The Future Information-Rich Warfare and the Mind of the Commander* (Westport, CT: Praeger Security International, 2007), 205.
38. Mark Pomerleau, "Can the Intel and Defense Community Conquer Data Overload?," C4ISRNET (website), September 5, 2018, https://www.c4isrnet.com/intel-geoint/2018/09/05/can-the-intel-and-defense-community-conquer-data-overload/; and Jane Edwards, "Army Seeks to Encourage Troops to Trust AI Through Project Ridgway; Col. Dan Kearney Quoted," ExecutiveGov (website), last modified September 24, 2021, https://executivegov.com/2021/09/army-seeks-to-encourage-troops-to-trust-ai-through-project-ridgway/.

negative effects of information overload as part of an Army-wide brain science education initiative can drive cultural change and improve decision making—with and without AI augmentation.

Adversaries

While the US military slowly integrates cognitive performance enhancement into its culture, China and Russia have made troubling advances in the cognitive domain. China emphasizes research and development aimed at creating an operational advantage in neuroscience, AI, and biotechnology as part of ongoing military-civil fusion efforts.[39] Influential People's Liberation Army (PLA) leaders, including Major General He Fuchu, vice president of the PLA's Academy of Military Science, emphasize military preparation for a future operating environment extending into virtual domains. According to He, these domains include the information domain and the "domain of consciousness" and require "mental/cognitive dominance" for success.[40] Elsa B. Kania, a senior fellow and China expert at the Center for a New American Security, observes that these concepts are now frequently discussed in PLA writings, along with the concept of human and artificial intelligence fusion.[41]

This interest is backed by billions of renminbi to fund research as part of the "China Brain Project" launched in 2016—a prime example of civil-military fusion efforts.[42] The project focuses on research into cognitive function with applied science in the areas of treating neurodegenerative diseases and the integration of the brain with artificial intelligence.[43] Participants' efforts include significant research into clustered regularly interspaced short palindromic repeats (CRISPR) gene editing in both animals and humans.[44] While the use of CRISPR remains a topic of global ethical debate largely due to its unknown consequences, Chinese scientists have already taken the

39. Kania, "Minds at War," 83.
40. Kania, "Minds at War," 85.
41. Kania, "Minds at War," 85–86.
42. Kania, "Minds at War," 85.
43. Olivier Dessibourg, "Primate Labs Give Us an Edge, Says China's Brain Project Chief," NewScientist (website), September 7, 2016, https://www.newscientist.com/article/mg23130900-800-primate-labs-give-us-an-edge-says-chinas-brain-project-chief/.
44. Elsa B. Kania and Wilson VornDick, "China's Military Biotech Frontier: CRISPR, Military-Civil Fusion, and the New Revolution in Military Affairs," *China Brief* 19, no. 18 (October 2019), https://jamestown.org/program/chinas-military-biotech-frontier-crispr-military-civil-fusion-and-the-new-revolution-in-military-affairs/.

unprecedented step of editing human embryos in ways that may enhance cognitive function.[45]

The lack of adherence to Western standards of ethical research features prominently in attempts to attract international neuroscientists to work in and for China.[46] Poo Mu-ming, chief of the China Brain Project, openly touts the large-scale use of nonhuman primates for brain research as an advantage over Europe, Japan, and the United States in an attempt to lure international scientists for seemingly cutting-edge research.[47] The direct involvement of the Chinese Communist Party in brain research ensures scientists studying neurological disease in China's aging population also provide People's Liberation Army leaders with the scientific horsepower to pursue their strategy of cognitive dominance.[48] Together these factors create a loosely-regulated, well-funded research environment with a national sense of urgency for dual-use neurological research breakthroughs that could be readily exploited by the PLA to enhance soldier cognitive performance.

Similarly, Russia sees the mind as the main battlefield in modern warfare where "wars are to be dominated by information and psychological warfare."[49] Russia mimics China's questionable adherence to ethical norms in cognitive dominance research, but the Russian approach relies more heavily on undermining adversary cognitive processes through psychological warfare and other means.[50] Ubiquitous false Russian narratives place high cognitive loads on their adversaries and require increased information filtering, which consumes cognitive resources and degrades the speed and quality of decisions over time. Numerous examples of this exist in the first six months of the 2022 Russian War on Ukraine. Dehumanizing rhetoric, acts of illegitimate annexation, and false claims about Ukrainians' affinity for Russia are narratives meant to obfuscate Russian aggression and create confusion.[51] By sowing doubt and creating confusion, Russian misinformation need only temporarily

45. Antonio Regalado, "China's CRISPR Twins Might Have Had Their Brains Inadvertently Enhanced," *MIT Technology Review*, February 21, 2019, https://www.technologyreview.com/2019/02/21/137309/the-crispr-twins-had-their-brains-altered/.

46. Palchik et al., "Dual-Use Brain Science," 112.

47. Dessibourg, "Primate Labs."

48. Palchik et al., "Dual-Use Brain Science," 112–13; and Kania, "Minds at War," 86.

49. Bērziņš, "New Generation Warfare," 173.

50. Gorman et al., *Silicon Curtain*, 78; and Bērziņš, "New Generation Warfare," 173.

51. U.S. Department of State, "Russia's War on Ukraine: Six Months of Lies, Implemented," 24 August 2022, www.state.gov/disarming-disinformation/russias-war-on-ukraine-six-months-of-lies-implemented/, accessed 16 October 2022.

cloud an enemy's judgment to cause hesitation and provide an advantage for Russian activities.[52]

Additionally, Russian forces show continued interest in using incapacitating agents to degrade their adversaries' cognitive function. During the 2002 Dubrovka Theater hostage situation, Russian special forces released a fentanyl derivative into the ventilation system to manipulate the consciousness of approximately 50 Chechen separatists and 750 Russian hostages. While their action caused separatists to lose consciousness, it also resulted in the overdose deaths of approximately 125 hostages and permanent debilitation of others.[53] Although Russian officials largely viewed the operation as a success, their actions drew international condemnation and renewed debate over the effectiveness and applicability of international law, such as the 1993 Chemical Weapons Convention.[54]

Neurology and biochemistry experts such as James Giordano, chief of neuroethics at Georgetown University Medical Center, fear advances in neuroscience and technology provide opportunities to exploit gaps in existing treaties, international laws, and supranational conventions governing the use of chemical and biological agents.[55] This includes the use of CRISPR gene editing and nanotechnology to enhance neural structures in soldiers while creating novel neuroweapons to degrade the cognitive function of their adversaries.[56]

Opportunities for the US Army

As Russia and China continue to ignore ethical boundaries related to human performance, the allure of leap-ahead technology and advances in neuroscience also garner much of the domestic media attention related to cognitive performance initiatives.[57] While these efforts are important and should continue, the US military must capitalize on practical, near-term opportunities to achieve cognitive dominance now.

Indirect and direct approaches to cognitive performance enhancement and optimization can provide quick wins for the Army at modest

52. James K. Wither, "Making Sense of Hybrid Warfare," *Connections* 15, no. 2 (Spring 2016): 82.
53. Mark Wheelis, " 'Nonlethal' Chemical Weapons: A Faustian Bargain," *Issues in Science and Technology* 19, no. 3 (Spring 2003): 74.
54. Peter Baker and Susan B. Glasser, "90 Hostages Killed in Moscow Theater," *Washington Post* (website), October 26, 2002, https://www.washingtonpost.com/wp-srv/articles/A21613-2002Oct26.html.
55. Joseph DeFranco, Diane DiEuliis, and James Giordano, "Redefining Neuroweapons: Emerging Capabilities in Neuroscience and Neurotechnology," *Prism* 8, no. 3 (2019): 51.
56. DeFranco et al., "Redefining Neuroweapons," 52–53.
57. Antonio Regalado, "Elon Musk's Neuralink Is Neuroscience Theater," *MIT Technology Review* (website), August 30, 2020, https://www.technologyreview.com/2020/08/30/1007786/elon-musks-neuralink-demo-update-neuroscience-theater/.

costs. Understanding that the direct-indirect dichotomy involves some oversimplification of complex cognitive and neuroscience concepts, these categories nevertheless provide a framework for discussion. Indirect approaches to cognitive performance enhancement affect cognition through dietary intervention, sleep modification, physical exercise, pharmacology, and resilience training. Direct approaches "immediately target the structural or functional mechanisms and processes underlying learning, perception, cognition, or emotion" and include methods such as transcranial electrical brain stimulation or reality augmentation.[58] In practice, no boundaries separate the two approaches, and both are required to effectively enhance and optimize cognitive performance.

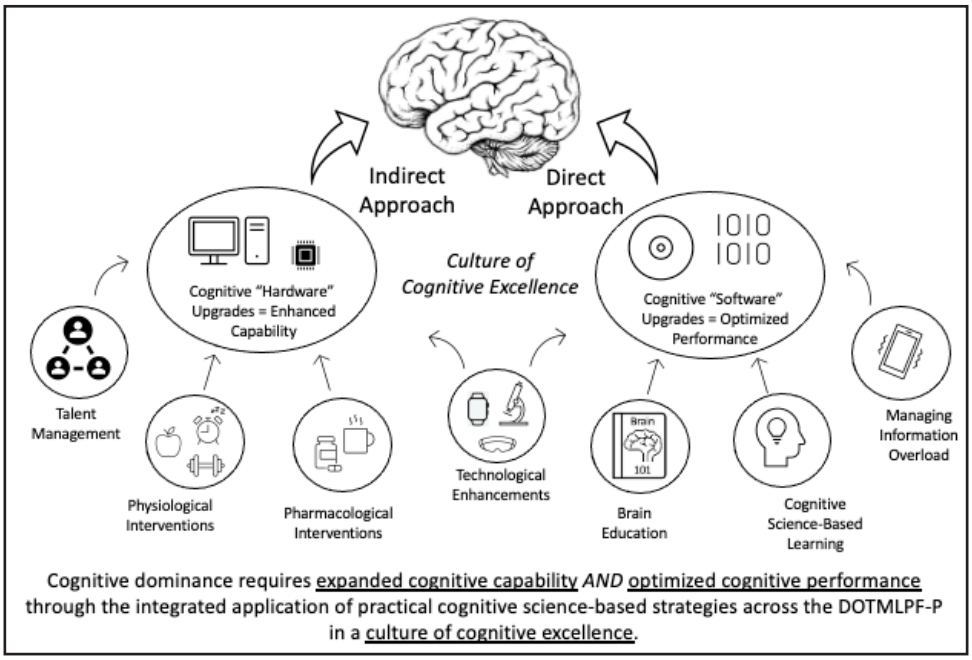

Figure 2. Integrated approach to cognitive dominance

Cognitive Hardware Upgrades – An Indirect Approach

Using a computer analogy helps visualize cognitive enhancement while building on the concepts of indirect and direct approaches. Cognitive performance optimization implies we maximize our software (cognitive abilities, or how we think) within existing limitations of our hardware (or physiology). In this context, both hardware and software upgrades can provide opportunities for cognitive enhancement. Hardware upgrades provide

58. Tad T. Brunyé et al., "A Review of US Army Research Contributing to Cognitive Enhancement in Military Contexts," *Journal of Cognitive* Enhancement 4 (February 2020): 3; and Wade Elmore, discussion with author, December 9, 2020.

an indirect approach through talent management, physiological interventions, pharmacological interventions, and technological enhancements.

Talent Management

In *Good to Great* (Harper Business, 2001), James C. Collins describes the first step to building a winning organization through the metaphor of "getting the right people on the bus, the wrong people off the bus, and the right people in the right seats."[59] Similarly, the Army's best opportunity to increase the collective cognitive operating capacity of the force may be in identifying, recruiting, assessing, and retaining the right people.

Studies show cognitive ability is partly hereditary, and identifying traits such as neural flexibility and skill expertise is possible by combining neuroimaging technologies, statistical tools, and traditional cognitive assessments.[60] These tools provide the Army with an opportunity to identify and optimize the application of individual cognitive traits as part of an Information Age recruiting and talent management program, promoting cognitive diversity to improve creativity and decision making. *Cognitive diversity* is defined as "differences in perspective or information processing styles."[61] Recent research indicates that cognitive diversity accelerates learning and enhances team performance in uncertain, complex scenarios.[62] Increased cognitive diversity on military teams could be enabled through an effective assessment and talent management program. Initiatives such as Project Athena offer a promising model for applying assessments as a self-development tool, but Army-wide implementation requires increased funding for research, development, and application.[63] In today's competitive job market, the Army must build on current assessment and talent

59. James C. Collins, *Good to Great: Why Some Companies Make the Leap…and Others Don't* (New York: Harper Business, 2001), 13.

60. Robert Plomin, John C. DeFries, Valerie S. Knopik, and Jenae M. Neiderhiser, "Top 10 Replicated Findings from Behavioral Genetics," *Perspectives on Psychological Science* 11, no. 1 (2016): 4–5; and Leonard Wong and Stephen Gerras, *Changing Minds in the Army: Why It Is So Difficult and What to Do about It* (Carlisle, PA: US Army War College Press, October 2013), 9, https://press.armywarcollege.edu/cgi/viewcontent.cgi?article=1514&context=monographs; and Royal Society, Brain Waves, 29–30.

61. Alison Reynolds and David Lewis, "Teams Solve Problems Faster When They're More Cognitively Diverse," *Harvard Business Review* (website), March 30, 2017, https://hbr.org/2017/03/teams-solve-problems-faster-when-theyre-more-cognitively-diverse.

62. Anita Williams Woolley, Ishani Aggarwal, and Thomas W. Malone, "Collective Intelligence and Group Performance," *Current Directions in Psychological Science 24*, no. 6 (2015): 422; and Reynolds and Lewis, "Cognitively Diverse."

63. Department of the Army, "Center for the Army Profession and Leadership: Project Athena Leader Self-Development Tool," Center for the Army Profession and Leadership (website), n.d., accessed January 17, 2022, https://capl.army.mil/athena/#/.

management efforts to recruit and retain the talent required to optimize its cognitive potential and outpace near-peer competitors.

Physiological Interventions

Numerous studies show that physical training, proper nutrition, and sleep management are clearly linked to cognitive capacity. The Army has long championed the psychological and physiological benefits of physical exercise, and studies confirm neurochemicals produced during endurance exercise have neuroprotective effects and can improve learning and memory.[64] Sleep management and nutrition guidelines are also reflected in the US Army's "Holistic Health and Fitness" (H2F) doctrine and its "Performance Triad Strategy," yet lack wide acceptance across the force.[65] Even though the Army recognizes the importance of proper nutrition in support of "optimal physical and cognitive function, soldiers often associate Army nutritional concepts with physical strength, body mass, and energy levels instead of mental function or mood."[66] For example, leaders are familiar with the physical effects of dehydration. The cognitive effects of dehydration, however, are less commonly known outside the medical and research communities.

Of the physiological interventions available to enhance cognitive performance, sleep management may hold the most untapped potential for Army application. Army H2F doctrine states that "[c]ognitive ability and readiness vary as direct function of the amount of sleep obtained" and numerous studies directly link sleep to cognitive function and operational readiness in the Army.[67] Even so, research suggests over 62 percent of soldiers suffer chronic sleep deficits, averaging fewer than six hours sleep per night, whether in garrison or deployed.[68] Deliberate cultural change through brain education during accessions training and all phases of professional military education is required for the Army to make meaningful progress on sleep management.[69] Education must be coupled with programs that recognize

64. Christopher Bergland, "Scientists Discover Why Exercise Makes You Smarter," *Athlete's Way* (blog), October 11, 2013, http://www.psychologytoday.com/blog/the-athletes-way/201310/scientists-discover-why-exercise-makes-you-smarter.

65. Department of the Army, *The Performance Triad Guide: Sleep, Activity, and Nutrition* (Washington, DC: Government Printing Office), https://ireland.tricare.mil/Portals/66/P3%20Guide.pdf.

66. Rosa María Martínez García, Ana Isabel Jiménez Ortega, Ana M. López-Sobaler, and Rosa María Ortega, "Nutritional Strategies That Improve Cognitive Function," *Nutricion Hospitalaria* 35, no. 6 (2018): 16–19; and HQDA, FM 7-22, 8-1.

67. HQDA, FM 7-22, 11-1; and Troxel et al., *Sleep in the Military*, 15–18.

68. DA, "Sleep Dispatch," 3.

69. Troxel et al., *Sleep in the Military*, 103.

and reward soldiers for establishing healthy sleep habits as part of a lifestyle of cognitive performance enhancement.

As the Army seeks to alter its culture, wider adoption of wearable technology could increase soldier and leader awareness, build desirable habits and practices, and alter mindsets. All three will be required to initiate enduring enhanced performance in the cognitive and physical domains. Studies by the Walter Reed Army Institute of Research (WRAIR) and the US Army Combat Capabilities Development Command Soldier Center involving hundreds of 10th Mountain Division soldiers show commercial off-the-shelf wearable technology such as watches, rings, or bands can drive behavioral changes at the individual and organizational level.[70] For instance, monitoring sleep habits and off-duty physical activity levels can help leaders coach their soldiers to establish healthy habits using personalized data. The Army should prioritize near-term investments in this area as quick and visible means to demonstrate commitment to enhancing cognitive performance. Combined with education and emphasis from leadership, the use of wearables could provide a powerful catalyst toward widespread cultural change.

Pharmacological Interventions

Similar to physiological interventions, pharmacological interventions offer opportunities for enhanced cognitive capacity. Stimulant use is one such intervention that is already pervasive in the Army. At the high end, medical providers prescribe drugs such as dextroamphetamine to aviators for sustaining cognitive performance and alertness on long missions. More commonly, soldiers consume caffeine to aid their individual performance.[71] While opportunities exist for further research and ethical debate on the use of cognitive performance-enhancing drugs such as modafinil (Provigil), methylphenidate (Ritalin), and various amphetamine mixes (Adderall), caffeine use is largely uncontroversial in Western society.[72] Even so, excessive caffeine consumption produces unwanted side effects, including insomnia, anxiety, increased blood pressure, and heart palpitations.[73] To reliably enhance

70. Adam Cucchiara, *Project Polar Unit Report*, (Camp Dwyer, Afghanistan, 4-31 Infantry Battalion, November 2, 2020), 3.

71. Paul Scharre and Lauren Fish, *Human Performance Enhancement* (Center for a New American Security, 2018), 7–9, http://www.jstor.org/stable/resrep20411.

72. Scharre and Fish, *Human Performance Enhancement*, 8.

73. Yolanda R. Arrington, "The Science behind Why You Should Stop Chugging So Many Energy Drinks," *Department of Defense News* (website), December 28, 2016, https://www.army.mil/article/180140/the_science_behind_why_you_should_stop_chugging_so_many_energy_drinks.

cognitive performance, a deliberate approach to stimulant use is required to achieve optimal levels of arousal without negative health consequences.

The *2B-Alert* application is one novel approach to optimizing caffeine usage with potential for use Army-wide. Currently in development by Walter Reed Army Institute of Research in collaboration with the Biotechnology High Performance Computing Software Applications Institute, *2B-Alert* uses machine learning, sleep history, and personal data to predict cognitive function during periods of sleep loss and develops a caffeine-dosing schedule to maximize alertness during desired time windows.[74] If integrated with wearable technology, incorporated into all training, and made a part of everyday military culture, applications like *2B-Alert* could provide safe and cost-effective cognitive enhancement across the Joint force.

Technological Enhancements

Multiple efforts across the DoD explore technology-based means of cognitive enhancement. These techniques vary widely in terms of development, methods of application, and cost but should be considered part of an overall cognitive dominance strategy. For example, transcranial electrical stimulation (TES) enhances brain signals to mimic brain waves found during deep, restorative sleep to improve sleep quality.[75] Thus, use of TES in a sleep-deprived environment could allow soldiers to gain more restorative effects from brief periods of sleep to enhance cognition. Ongoing studies by the Walter Reed Army Institute of Research Sleep Research Center, partnered with the Defense Advanced Research Projects Agency (DARPA) and Teledyne Scientific, are assessing the effectiveness of a fieldable TES device to make the most of limited sleep periods and improve fatigue management.[76]

Transcranial direct-current stimulation (tDCS) is already in use by Olympic athletes and undergoing testing within the Department of Defense. Unlike transcranial electrical stimulation, tDCS works by increasing energy in the brain to promote neural activity and alter brain connections to improve motor performance and cognition. Initial testing by Navy special operators shows tDCS can improve training efficiency, and Air Force studies show

74. DA, *Sleep Dispatch,* 6; and Telemedicine and Advanced Technology Research Center, Military Operational Medicine Research Program, and US Army Medical Research and Development Command, "*2B-Alert* Web: Predictions on the Effects of Sleep/Wake and Caffeine on Alertness," Biotechnology HPC Software Applications Institute (website), https://2b-alert-web.bhsai.org/2b-alert-web/login.xhtml.
75. Tina Burke, discussion with author, December 10, 2020.
76. DA, *Sleep Dispatch*, 9.

increased vigilance and enhanced cognition under fatigue using transcranial direct-current stimulation.[77]

Biotechnological and pharmacological cognitive enhancement is sparking ethical debate regarding the liberty of soldiers to consent to enhancement and the long-term repercussions of enhancing a segment of society.[78] The Army should engage in this debate as it continues its enhancement research efforts to keep pace with near-peer competitors. Recognizing these ethical limitations and budgetary constraints, however, the Army should place more emphasis on readily executable and less controversial efforts in the near term.

Cognitive Software Upgrades – A Direct Approach

Revisiting our computer analogy helps illustrate that enhanced cognitive software—how we use our minds—provides a direct approach to cognitive performance enhancement. While indirect steps can improve cognitive hardware, better hardware alone may not enhance performance. New hardware often requires upgraded software and greater user proficiency to maximize its potential. Therefore, direct and indirect approaches—upgraded hardware *and* software—are necessary to achieve the highest levels of cognitive performance. Brain education, cognitive science-based learning techniques, and methods of managing information overload offer practical software upgrades for minimal investment.

Brain Education and Self Awareness

Many cognitive psychologists and neurologists agree the optimization of individual cognitive performance starts with understanding the brain.[79] A basic understanding of brain function sets the stage for metacognition, or "thinking about thinking." Army doctrine values metacognition for complex problem-solving and adaptive thinking but provides little insight into how to develop and improve metacognitive processes.[80] Moreover, the scant writing on metacognition in Army doctrine focuses entirely on leaders in a complex problem-solving context and fails to account for broader application across the force. In his 2011 thesis on applying neuroscience to enhance cognitive performance in the Army,

77. Scharre and Fish, *Human Performance Enhancement*, 9.
78. Gareth W., "Hacking Brains: Enhancing Soldier Cognitive Performance," Wavell Room: Contemporary British Military Thought (website), June 25, 2020, https://wavellroom.com/2020/06/25/hacking-brains-enhancing-soldier-cognitive-performance/.
79. Peter C. Brown, Henry L. Roediger III, and Mark A. McDaniel, *Make It Stick: The Science of Successful Learning* (Cambridge, Massachusetts: Belknap Press, 2014), 7; Rock, Your Brain at Work, 1.
80. Department of the Army, Army Field Manual (FM) 6-22, *Leader Development* (Washington, DC: Government Publishing Office, 2015), 5-2.

Andrew Steadman observes, "metacognition has not [yet] descended to the tactical level as a desirable leader trait and training concept."[81]

Universal training and education of service members on basic brain science and metacognition can create the foundation for peak cognitive performance when complemented by an individual's ability to observe brain processes in real time.[82] Metacognition is accomplished through mindfulness, or paying close attention to the present moment "on purpose and without judgment."[83] Multiple neuroscience and psychology studies reveal significant benefits from practicing mindfulness, including improved cognitive control and decision making.[84] The Army incorporates mindfulness training as part of the Comprehensive Soldier and Family Fitness program and recognizes the concepts of mindfulness and mindful awareness in Army H2F doctrine and coaching.[85] The concepts of mindfulness and mindful awareness, however, lack a widespread understanding and adoption across the force.

Brain science, metacognition, and mindful awareness must be integrated into professional military education to optimize soldier cognitive performance across the Army. The Applied Critical Thinking course offered by the US Army's University of Foreign Military and Cultural Studies offers baseline curriculum content for field grade pre-command courses and the Army Strategic Education Program.[86] These topics should also be taught across all initial entry training pipelines, tailored to skill and experience level, and customized based on career-long assessment results. This approach is similar in many ways to the Navy's Warrior Toughness program, which focuses on the development of sailor spiritual, mental, and physical strength and has seen promising initial results.[87]

The Navy implemented the Warrior Toughness curriculum across all enlisted and officer accessions programs in 2018 after reviewing recent accidents aboard USS *Fitzgerald* and USS *John S. McCain*.[88] It uses mindfulness and the sports psychology techniques of goal setting, self-talk, visualization, and energy management to improve emotional regulation and

81. Steadman, *Cognitive Performance in Combat*, 24.

82. Rock, *Your Brain at Work*, 87.

83. HQDA, FM 7-22, 13-3; and Rock, *Your Brain at Work*, 89–90.

84. Elizabeth A. Stanley and Amishi P. Jha, "Mind Fitness: Improving Operational Effectiveness and Building Warrior Resilience," *Joint Force Quarterly* 55, no. 4 (2009): 147–48; and Rock, *Your Brain at Work*, 86–89.

85. Brunyé et al., "Cognitive Enhancement in Military Contexts": 6; and HQDA, FM 7-22, 13-3.

86. "Red Team Education," United States Army Combined Arms Center (website), https://usacac.army.mil/organizations/ufmcs-red-teaming.

87. Michael Bernacchi, Stephen Drum, Jennifer Anderson, and Kathleen Saul, "Warrior Toughness: Making the Mind, Body, Soul Connection," *Proceedings* 145, no. 7 (July 2019), https://www.usni.org/magazines/proceedings/2019/july/warrior-toughness-making-mind-body-soul-connection; and Melissa D. Hiller Lauby, "Navy Warrior Toughness Program" (Microsoft Teams presentation, 2020 Performance Psychology Summit, Microsoft Teams, November 12, 2020).

88. Lauby, "Navy Warrior Toughness Program."

cognitive performance.[89] The implementation of Warrior Toughness marks a significant investment in cultural change across the Navy, the results of which are thus far difficult to quantify. Anecdotally, US Navy clinical psychologist Captain Melissa D. Hiller Lauby notes sailors successfully responding to the fire aboard USS *Bonhomme Richard* in July 2020 referenced the benefits of Warrior Toughness training on multiple occasions during after-action debriefings. Specifically, the use of self-talk and emotional regulation helped some sailors respond more calmly in the face of extreme stress.[90] Additional time and analysis are required to judge the effectiveness of the program, but Warrior Toughness could inform Army efforts to change its cognitive performance culture.

Cognitive Science–Based Learning

Training is ubiquitous in the Army, but recent cognitive science research demonstrates how many of the Army's training techniques may fail to produce long-term comprehension. Cognitive science shows repetitive drills, rote memorization, and rereading are not as effective as many believe.[91] Research in academic situations and with athletes attempting to master motor skills, such as hitting a baseball, reveal that changing how instruction and training are provided greatly influences the quality and durability of learning.[92] Adoption of cognitive science-based learning methods such as spaced practice, interleaving, and adaptive tutoring can provide the Army with low-cost opportunities to maximize the effectiveness of education and training to improve cognitive performance.

Furthermore, Army Field Manual (FM) 7-22, *Holistic Health and Fitness*, states cognitive science-based learning strategies, which control the learning environment, limit interruptions, and tailor instruction to soldier learning preferences, can result in more effective task mastery.[93] Wade Elmore, an applied cognitive and brain science expert at Army University, sees the opportunity for adaptive tutoring technology to increase durable learning.[94] Studies indicate intelligent tutoring platforms using machine learning and computer algorithms to deliver customized instruction outperform all other

89. Bernacchi et al., "Warrior Toughness."
90. Lauby, "Navy Warrior Toughness Program."
91. Brown, Roediger, and McDaniel, *Make It Stick*, 9.
92. Sarma and Yoquinto, "Cramming May Help for Next-Day Exams, but for Long-Term Memory, Spacing Out Study Is What Works," *Washington Post*, November 30, 2020, https://www.washingtonpost.com/health/memory-and-cramming-for-exams/2020/11/27/d395a838-29bd-11eb-8fa2-06e7cbb145c0_story.html.
93. HQDA, FM 7-22, 9-3.
94. Elmore, discussion with author, December 9, 2020.

methods, including human tutors.[95] Although intelligent tutoring may not directly enhance decision-making and critical thinking skills, increasing soldier tacit knowledge through a tailored approach to enhanced learning provides a basis for subsequent mastery of related cognitive tasks.[96] Cognitive science-based learning methods and technology must be adopted throughout Army training, incorporated into Army training doctrine, and integrated into Army training culture. Increasing the quantity and quality of durable knowledge and skills embedded in soldier long-term memory is a powerful way to optimize cognitive software for peak performance.

Managing Information Overload

While cognitive science-based learning methods and technologies can assist with optimizing learning, improving soldier short-term working memory requires a different approach. Army doctrine recognizes this and asserts in FM 7-22, *Holistic Health and Fitness*, that soldiers who optimize their short-term working memory can process and complete complex tasks more effectively.[97] The manual goes on to offer task simplification, learning cues, and memory cues as ways to boost performance but stops short of a more comprehensive approach and misses an opportunity to influence Army culture in this critical area.

Offsetting the effects of information overload requires a fundamental change to the Army's "always on" culture of communication and information management. The expectation that leaders in particular are always available for instantaneous communication degrades cognitive performance through frequent interruptions, distractions, and emotional arousal.[98] Education on the effects of multitasking, distraction, frequent interruption, and information overload as part of an Army-wide brain science education initiative could provide an important first step in driving change.

Effective time management provides another opportunity to reduce mental friction and boost cognitive performance.[99] The demands of daily operations often test leader time-management skills. Yet, effective time-management techniques are not taught systematically in professional military education below the senior service college level. Consequently, many leaders

95. James A. Kulik and J. D. Fletcher, "Effectiveness of Intelligent Tutoring Systems: A Meta-Analytic Review," *Review of Educational Research* 86, no. 1 (March 2016): 67, https://journals.sagepub.com/doi/10.3102/0034654315581420.

96. Brown, Roediger, and McDaniel, *Make It Stick*, 18–19.

97. Alan Baddeley, "Working Memory," *Science* 255, no. 5044 (January 1992): 559, http://psych.colorado.edu/~kimlab/baddeley.1992.pdf; and HQDA, FM 7-22, 9-3.

98. Rock, *Your Brain at Work*, 131.

99. Levitin, *The Organized Mind*, 175–76.

are unaware of cognitive science-based best practices for time management and execute daily schedules that guarantee suboptimal cognitive performance. Increased education in this area could help leaders create daily schedules that avoid distractions during creative times, provide opportunities for focused work, and support adequate sleep and nutrition.

Conclusion

Cognitive capability is the foundation of individual and collective performance in all domains. As the US Army prepares for multi-domain operations, establishing the culture and behaviors that promote cognitive dominance is essential to compete successfully with near-peer adversaries seeking asymmetric advantages across multiple domains. To succeed, the Army must replace its "always on" culture of multitasking and connectivity with a culture of cognitive performance optimization and enhancement to dominate and win in the Information Age. It is only through a deliberate approach rooted in education, training, technology, and hard work that the US Army can establish a lasting culture of cognitive dominance.

While it is tempting to bet solely on technological advances to achieve cognitive dominance, a diversified approach across the doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policies (DOTMLPF-P) framework is required to reduce risk in a time of budgetary and operational uncertainty. The Army must incorporate both indirect and direct approaches to cognitive performance enhancement while engaging in the ethical debates associated with these methods. America's future adversaries will continue to seek an asymmetric advantage in the cognitive domain. We must force them to try to overcome the determination, creativity, and grit of the American soldier to achieve it.

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