SYNESIS
A JOURNAL OF SCIENCE, TECHNOLOGY, ETHICS, AND POLICY

Introduction

On the need for neurotechnology in the national intelligence and defense agenda: Scope and trajectory

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In light of the recent advances in neuroscience and neurotechnology, we posit that intellectual and empirical commitment to brain science is critical to national security. Moreover, we believe it is equally important to have a commitment to translational research, or at very least, devoted attention to the steps essential to progressing science from theory to application. Our position is that while there is no shortage of science and intellectual consideration, there is a substantive gap in our understanding of how to engage this knowledge toward useful — and ethically sound — ends.

Whether the basis for improved human performance or more intelligent machines, the impacts of neuroscience and neurotechnology will be far-reaching, change the landscape of human capabilities, and will necessitate re-address of guidelines, policies and practices (1, 2). The ratio of applications to discoveries in brain science is high, and international advances in neuroscience and neurotechnology highlight the importance of maintaining US competitiveness in these areas.

For example, researchers at the Max Planck Institute in Germany have demonstrated capability to predict test subjects' decisions for simple choices based on neuroimaging-based assessment of brain activity arising prior to the subjects' conscious awareness of their decision (3). Employing such findings beyond the laboratory, it might thus be possible to develop human-machine systems that could enable an operator's intentions to be anticipated and controlled well before conscious initiation of action(s) (4). As well, research institutes in different nations have engineered nanomaterials to sense and manipulate activity at the single-neuron level. Such nanosubstances could be delivered to the central nervous system (CNS) to induce specific effects on targeted regions and functions of the brain and/or spinal cord. Researchers at the RIKEN Center in Japan have manipulated the genetics of embryonic stem cells to cultivate neural precursor cells that when transplanted into a living mouse, self-organize to form neural circuits that integrate with existing neural tissue to enable normal brain activity (5). This creates the potential to alter the neural genome, phenome and connectome in ways that induce short- and long-term structural and functional changes to affect brain activity relevant to cognition, emotion, and/or behavior. It is not difficult to imagine how an increasingly embellished, or widespread use (or misuse) of these technologic applications could impact not only human thought, and action, but also more fundamental constructs of beliefs, intention, and the nature, meaning and contexts of various socio-cultural interactions. These possibilities illustrate the ways that sustained investments in basic and applied neuroscience and neurotechnology can be directed at the structure of the brain and its function(s) — viz. – the "mind" — to incur profound impacts upon aspects of human cognition and behavior that are relevant and important to security and defense.

As with other scientific and technical innovations (e.g., flight, nuclear physics), the dual-use (i.e., civilian and military) capability of neuroscience is apparent. Since the early 20th century, technologies that affect the nervous system, and brain~mind have been employed in national defense (e.g., nerve gas, attempts at "brain-washing" techniques of interrogation, etc.). The speed and sophistication of new developments in neuroscience and neurotechnology (as well as the linking of existing devices and technology to innovative approaches; e.g., nanoscale delivery systems; genetic tools, etc. within a directed program of integrative scientific convergence) are such that the breadth and depth of this progress demands continuous re-address, re-appraisal, and reflective governance (1). While ethical caveats have restricted neuroscientific research in US national security and defense (at least to some extent), it cannot (nor should not) be overlooked that other nations are making tremendous investments in brain science, and much of this research could provide a basis for offensive capabilities. In response to these potential threats, we posit that it is important that the United States conduct research to examine and evaluate how and what neuroscientific neurotechnologic advancements may be employed in these ways, so as to anticipate, be prepared for, and perhaps counter such intelligence and military application(s) of brain science by our (current and future) adversaries. But while an emphasis has primarily been upon anticipating threats posed by other nations, we believe that it is equally important to emphasize United States' capabilities so as to remain ahead of — or at least in step with — any international competition in these areas, and in this way, not render our national security vulnerable. But, surveillance, identification, analysis and a forward-looking program of research development testing and evaluation (RDTE) does not imply our developing and stockpiling potential neuroweapons. If the nuclear age has provided any lesson at all, it is that any programs of mutual, mass accumulation of weaponry is both self-perpetuating, and generally problematic. Rather, we posit that a viable goal is to develop and utilize neurotechnologies to maximize national intelligence efforts, and apply such intelligence methods to deep analysis of the field and the assessment and mitigation of any/all international efforts that might be considered as potential threats. Indubitably, new threats will emerge that could be difficult to mitigate without sufficient information and knowledge of the strengths and limitations in other nations' existing and potential neuroscientific and neurotechnological capabilities. Thus, attention to augmented cognition technologies, and its employment in education and training, as well as operational field use, are of vital importance, both at present and in the future.

In this light, we have identified four interactive areas of neuroscience that could affect and be important for national security; these are:

1. *Nano-neuroscience*: Nano-substances and devices may be engineered to alter neural networks, induce changes in properties of the nervous system from periphery to brain, and affect sensitivity to internal and/or external stimuli. Nano-neurotechnologies could therefore be used to modify cognitive, emotional and/or behavioral functions, and in this way affect mental and motor capacity, alter mood or cause near- and long-term disability. Such capability might be used to modify the function of national intelligence and security personnel, and/or could be employed in a) combat (both to enhance performance of troops, as well as impair function of enemy warfighters) and/or b) by our enemies as a form of biological-technological terrorism and a means of mass subjugation.
2. *Advanced neuropharmacologicals*: Augmented cognition and neural performance improvement (and/or degradation) can be achieved through the use of psycho-neuropharmaceuticals. As mentioned above, these agents could be administered via nano-delivery systems that allow enhanced access to the central nervous system (CNS) in ways that maximize biological (and ultimately psycho-social) effect(s), yet could easily elude detection. Similarly, pharmaceuticals can be linked to brain stimulation technologies (*vide infra*) to synergize effects in modifying specific cognitive, motoric, emotional and/or behavioral processes.
3. *Neuro-imaging and neuro-manipulative devices*: Current and prospective developments in neuroimaging offer the potential to visualize relatively site- and network-specific brain processes that are putatively involved in (or may explicitly subserve) various cognitive-emotional and behavioral functions. Identifying these neurological axes could provide means to investigate — if not "detect" and/or "reveal" — mental states. But imaging alone, at least in its current iteration(s), while useful in the scientific and medical investigation of cerebral function, may be of limited utility for practical applications of brain~mind science for intelligence and defense purposes. Efforts are underway that focus more upon measuring (i.e., quantifying and qualitatively defining) brain activity, in attempt to provide indications of "what", if not "why" cognitive and/or emotional processes (such as deceit, intent, aggression, etc.) occur. Obviously, this has given rise to hypothetical "mind reading" scenarios, and, like other aspects of neurotechnological research and applications, has prompted considerable debate about the validity, value and ethical implications of such devices and techniques. Moreover, imaging/measurement can be yoked to neuro-interventional technologies (e.g., transcranial magnetic stimulation, pharmacologicals) to guide or enable manipulation of

neurological activity. Simply put, near-future iterations of these technologies (either as stand-alone modalities, or if used in convergence) makes the notion of biotechnologically "altering brains" to "changing minds" evermore viable.

4. *Neuroinformatics and cyber-neurosystems*: The linking of rapidly advancing computational capability to neurotechnology has established three major domains of progress. The first is the use of computational systems and models to augment human cognitive processes (i.e., human-computer interfaces), the second is in reverse-engineering cognitive mechanisms to create computational techniques and systems to achieve efficient and robust machine intelligence(s), and the third is the data banking of information (about neural structure — including genotypes — and function) to facilitate real-time access, analyses and use.

These areas provide foci for iterative work that seeks to 1) survey and elucidate any and all research, development, testing and evaluation in the field, world-wide; 2) recognize the operational capabilities established by such RDTE; 3) accurately depict the current and projected state-of-the-science, and 4) predict possible benefits, burdens, risks, and consequences of such science-in-application(s), 5) propose strategies and tactics to enhance potential benefits, and prevent or mitigate any negative trajectories of use, 6) establish the utility, breadth of application and constraints of those technologies deemed (through a process of dialectic, reflective analysis of benefits and risks) to be of greatest benefit to US' national interests and security, and 7) dedicate efforts and economic support toward engineering such technologies. To be sure, these tasks, and the development and use of specific neurotechnologies are germane to the national intelligence and defense community.

Thus, the current issue of *Synesis: A Journal of Science, Technology, Ethics, and Policy* is devoted to a review of this field. Neuroscience is a relatively new discipline, titularly arising in the 1970s as a formal conjoinment of psychology and the natural sciences focused upon the structure and functions of neurological systems. Yet, by engaging tools and theories from constituent fields of anatomy, chemistry and physiology, neuroscience made ardent strides in understanding and being able to manipulate the brain. The potential of neuroscience to manifest capabilities to profoundly affect the human condition and predicament was the imperative for the congressionally declared Decade of the Brain (1990-2000), a federally funded research initiative directed at further catalyzing progress in neuroscience and neurotechnology.

As Jonathan Moreno notes, neuroscience and neurotechnology are dynamic fields that are punctuated by rapid changes in the scientific, cultural, political and economic domains, and each and all of these domains manifest effects that can influence how neuroscience might be utilized in national security and defense agendas. The use — and possible misuse — of cutting-edge neuroscience and technologies in national defense advance existing dilemmas, give rise to new practical, ethical, legal and social issues, and compel ongoing examination, analysis, and discourse of the promise and problems incurred.

One of the criticisms levied against the Decade of the Brain is that it failed to enthuse and/or increase operational translation(s) from basic and clinical research endeavors. Mary Layne Kalbfleisch and Chris Forsythe show how neuroscientific and technological progress could enthuse efforts in national intelligence and defense, across a range of potential applications. Steve Murray and Matthew Yanagi posit why, how, and what research can — and should — be articulated from laboratory to field use(s), and Kelvin Oie and Kaleb McDowell describe how novel neurotechnologies can be operationalized within intelligence and security systems' applications. Such systems can be employed to facilitate information acquisition, analysis and distribution. As Kay Stanney, Kelly Hale, Sven Fuchs and Angela Baskin show, such information transfer is particularly important to intelligence and defense training, as a means of enhancing human operator capability by incurring leftward shifts in skill and knowledge acquisition, and by enabling viable tasks sharing between human and neurotechnological (e.g., computational) resources.

Given the potential threats to public health posed by epi- and pandemics (induced by international travel, and nodal and edge patterns of human interactions), as well as terrorist activities, it becomes obvious that the neurotechnologies discussed in these papers are not only important to the intelligence community, per se, but are equally vital to national defense and protection to enhance surveillance and analyses applications in operational medicine; Carey Balaban discusses the current and planned uses of neurotechnology in such operational medical paradigms that serve public health, and national preparedness and resiliency. While the concept of 'dual use" characteristically refers to military and civilian applications, James Giordano and Rachel Wurzman afford a reminder that "dual use" of neuroscience and neurotechnology may possess another, inherently Janusian character, in this context, having the potential to develop "neuroweapons" that can be employed both offensively and defensively, and for potentially positive and negatively valent ends.

We concur with Dr. Moreno's assessment, and argue that the time is right to address progress and viable applications of neuroscience and neurotechnology in national security and defense. It is our hope that this issue represents a meaningful step toward such objectives.

Acknowledgements

This work was supported, in part, by funding from the Center for Neurotechnology Studies of the Potomac Institute, Arlington, VA, a grant from the Office of Naval Research (JG) and by Sandia National Laboratories (CF). Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.

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Competing Interests

The authors declare that they have no competing interests

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