Policy Memorandum to John P. Holdren: Expanding Our Neurotechnology Initiative

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Executive Summary: Neurotechnology, defined as any artificial means to interact with the workings of the brain, has the potential to transform every aspect of our daily lives. Neuro-enhancement technologies are emerging rapidly and have the potential to maximize the physical, cognitive, innovative, and technological abilities of each individual in our society. From drugs and stimulation devices promising enhanced cognition to brain-computer interfaces offering to expand access to collective human knowledge, this technology holds tremendous value. In this memorandum, I call on the White House to expand the current BRAIN initiative to provide increased support for a neurotechnology industry and to place greater priority on creating the infrastructure necessary for this developing industry to flourish.

I. A New Era

For decades, scientists have been electrically stimulating the brain and observing the subsequent response in order to understand the relationship between different parts of the brain and the motor units that they control (Fritsch and Hitzig 1870). However, we have only recently developed the technology to use neuro-stimulation to our advantage. We can now enhance cognitive functions by acting directly on the nervous system to increase its performance (Nicolelis 2003). In a recent example, a team of neuroscientists genetically modified rats to express an "on/off switch" within a particular type of brain cell, or neuron. This modification allowed scientists to stimulate specific neurons while the animal selected between different choices based on their visual appearance (Lee et al. 2012). When they applied targeted stimulation to these neurons, the rats were significantly better at the making the 'correct' choice in regards to a specific task. Neuro-enhancement effects such as these, if successfully implemented in humans, could provide us with similar control over our own performance during visually demanding tasks.

Comparable enhancement has already been achieved in humans as well by inducing electrical changes on the surface of the skull (Clark and Parasuraman 2014). In 2003, a group of German neuroscientists found that the excitability, or potential of a neuron to send a message inside the brain, could be increased by applying weak electric currents to the surface of the head (Nitsche et al. 2003). Since then, others have used this technology to evoke improvements in "attention, perception, memory and other forms of cognition in healthy individuals" (Clark and Parasuraman 2014). As an example, Nelson and colleagues recently demonstrated that it is possible to manipulate and even extend the attention span of healthy individuals using precisely localized delivery of such currents into the brain (Nelson et al. 2014). Although results are still emerging, neuro-enhancements such as these may be well suited to help improve our performance in the home, workplace, and beyond.

II. The Future is Now

Neuro-enhancement technology is here. At the Consumer Electronics Show -- where the latest electronic inventions are debuted before hitting the marketplace -- the number of neuro-enhancement

devices being showcased has been expanding rapidly since 2010 (CESweb 2014). The demand to push the industry forward is not just coming from a few isolated entrepreneurs. Some of these products brandish familiar labels such as Intel, Mattel, and Hewlett-Packard. Currently, in the absence of regulation by state or federal officials, devices are available that can detect changes in electrical fields around the brain to effectively "read" your mind (Debener et al. 2012). Perhaps most note-worthy is the capability of these devices to send electrical currents into the brain -- the effects of which we are only beginning to understand (Soekadar et al. 2013) -- in order to improve the user's cognition, mood, and/or sleep. Neuro-enhancement technology exists and is likely to continue occupying an increasing share of the consumer electronics market.

Historically, the government has been a significant driver in the emergence of new technologies. Investments in computing, transportation, space systems, and nuclear power have transformed society and enabled continued progress into areas beyond the original scientific application (Brooks 1994). Take for example our government's early investment in the Internet, and the wave of innovation that has followed. Similar investments have driven the growth of the nanotechnology industry as well, providing new opportunities for venture capital funding (Paull et al. 2003). National investments such as these bolster science research, but they also create an industry for technology that empowers communication and learning, while amplifying our economic productivity. But, unlike other markets such as nanotechnology, the direct-to-consumer neuro-enhancement industry is currently without regulation or oversight by an appointed government body. Regulatory approval for neuropharmacological drugs and devices are currently hindered by an unclear regulatory processes and limited research resources. To overcome this, funding should be established for the Food and Drug Administration to increase their capacity for neuroscience-related applications and to establish clearer standards and regulation for the neurotechnology industry.

The capabilities of neurotechnology are advancing quickly and a balanced approach to regulation is necessary. The market has already become populated with diverse business interests, and regulatory conflicts analogous to "net neutrality" are sure to follow. The market is ready for neurotechnology, and the commercial world has already invested heavily. However, in order to succeed, this market still requires a rigorous, experimentally validated set of technologies delivered by a network of trusted providers. The government should encourage and provide the necessary research and funding to develop the applied neurotechnologies that fit into this framework.

III. Beyond the BRAIN Initiative

In 2013, the Obama administration announced a joint research initiative, which sought to provide a complete description of the connections between all 100 billion neurons in the human brain (NIH 2015). In their approach to this initiative, scientists and engineers across many diverse disciplines and sectors are collaborating under the coordination of the National Institutes of Health Advisory Committee. A portion of the funds from this Initiative will be directed toward the development of more powerful research tools to explore the brain, such as high-resolution imaging technologies.

While this initiative certainly amounts to progress, the level of facilitation, oversight, and fiscal support it provides is wholly insufficient to invigorate emerging neurotechnological industries. For neurotechnology to become as prevalent as computing technology, we will need to make comparable investments in infrastructure. We need to expand funding for existing neuro-technology related programs, such as the Small Business Innovation Research and Small Business Technology Transfer programs, to accelerate innovation in this arena.

Continued progress in the next technological revolution will require a national neurotechnology initiative that is well funded, coordinated across cooperating agencies, and integrated with other fields in science and technology. To serve as a unified voice for federal neurotechnology concerns, an office should be established to improve coordination among agencies.

These achievements require our leaders to make greater investments in neurotechnology, on par with our past investments in nanotechnology and information technology. In order to match America's previous national investment successes (including the Apollo program and the National Nanotechnology Initiative), this initiative would require at least 20 times what the President has included in his

discretionary spending budget (The White House 2015).

IV. Moving Beyond Medicine

Up to this point, the majority of brain research has been motivated by the repair of dysfunction, rather than the extension of function. There is no doubt that the prevention and treatment of disease remain among the most important goals that our society can and should continue to pursue. Improvements in medicine over the last century have led to the dramatic improvements in infant mortality rate (Meckel 1990), life expectancy (Oeppen 2002), and quality of life (Bunker 2001) that we can see in our world today. However, in order to maximize the overall benefit of society by developments in science, we cannot ignore the ways in which technology can improve the abilities of healthy individuals as well. The enhancement of healthy subjects offers additional benefits in education, communication, intelligence, our economy, and much more. Technologies such as brain stimulation, prosthetic brain chips, and cognition-enhancing drugs may soon allow us to augment our mental abilities at home, in school, or the workplace. It may eventually be possible use these tools to produce specific behaviors, like relaxation or more efficient learning. In order to achieve these benefits, we must not restrict neurotechnology to improvements in medicine. We must also develop additional applications for other important areas including economics and education. In doing so, we are promoting the advancement of our society into the next major technological era.

V. Conclusion

The magnitude of this transition within the modern history of mankind cannot be overstated. With these tools, our species advances from one that employs technology to supplement our abilities to one that integrates technology to enrich those abilities.

Our use of tools has been a primary factor in the survival of our species for 6 million years (Anton et al. 2014). Moore's Law tells us that as technology develops over time, it necessarily does so at exponentially increasing speeds (Moore 1998). Computing, artificial intelligence, nanotechnology, biologics, and now neurotechnology are fields that, together, are reaching new heights. The synergistic nature of these advances means that new paradigms and technologies for enhancing humans are developing faster than ever. An ever-growing knowledge base and the capacity to consume that knowledge is becoming the new norm. We stand at the boundary of a dramatic shift in the way we interface with our world.

Despite the challenges inherent in this transition, it is incumbent upon our leaders to maximize the potential of this technology for the benefit of society. By expanding our nation's investment in neuro-enhancement technology and providing the necessary infrastructure, this developing industry will flourish. We should let this experience serve as an opportunity to establish a national agenda for approaching future technology concerns, as they are certain to continue to emerge.

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