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Losing Your Mind

Imagine sitting in a room where every individual is able to read every other individual's mind. Would you lose your mind?

We are living in an age where many of us have already surrendered our personal privacy to online interfaces either knowingly or by deceptive means. As technology continues to advance, we are likely to lose even more of our personal space and identity, unless legislation catches up to keep pace with the transformative changes around us. Nicholas Carr, author of the 2011 Pulitzer Prize finalist *The Shallows: What the Internet Is Doing to Our Brains,* went further by claiming that the Internet is having detrimental effects on our brains and cognition. According to him, "We become, neurologically, what we think," a fact that is in line with studies in the cognitive sciences showing that our thoughts can change and rewire our brains, thus potentially altering or enhancing some of their functions. Albert Einstein was perhaps perceptive of this cognitive norm when he stated, "It is not that I am so smart, it is just that I stay with problems longer."

The online world we live in is not only altering the personal space around us but is also having an effect on our inner selves. And there is yet more to come! Today, we are moving in new technological directions that can literally "take control" of our minds and brains, whether for good or bad, with machines that can read our brain waves and infer our thoughts [1]. The technology is taking its first steps but is rapidly building up strength. Many valid ethical and legal ramifications will arise in this domain, in addition to questionable practices and applications. One would expect that common sense would prevail, although this can never be taken for granted. To paraphrase Voltaire, sometimes "common sense is not so common." I will not delve into these issues here. My focus will be on the potential for scientific discoveries and the role our signal processing discipline can play in advancing knowledge.

The ancient Egyptians had little regard for the brain. During mummification, they would remove brain tissues through the nostrils and discard them. We have come a long way since then and now recognize the power and central role of not only the human brain, but also of the human mind and our thought process. One of the most promising and mysterious frontiers for engineering, life sciences, and cognitive sciences is joining forces to explore the human brain and mind. Eric Kandel, the 2000 Nobel Laureate in Physiology from Columbia University declared in his speech at the Nobel Banquet [2] "The biology of the mind will be as scientifically important to this century as the biology of the gene has been to the 20th century." Our signal processing discipline can help perfect the tools and sensors to make this focus a reality by helping probe the biological environment more thoroughly, analyze massive brain data more closely, and develop inference tools to learn and predict thought patterns, as well as restore or augment neural functionality.

According to the World Health Organization (WHO), an estimated 1 billion people suffer from neurological disorders [3]. These are disorders of the nervous system including brain damage, spinal cord injury, epilepsy, paralysis, Parkinson's disease, Alzheimer's disease, multiple sclerosis, migraines, and other related ailments. Neurotechnology offers great potential to treat patients with such disorders, help restore functionality, and permit healthy aging. Interest and progress in the field will be driven by several ongoing trends in technology that open the way for new discoveries and treatments.

On one hand, our increased ability to design and control miniaturized devices, coupled with advances in sensing and nanotechnologies, is changing the way we probe and interact with living cells. At the same time, progress in invasive and noninvasive procedures, coupled with advances in new materials and wireless technologies, is allowing us to monitor the biological environment ever more closely and continually. Likewise, advances in powerful imaging modalities, coupled with computing power, storage capabilities, and intelligent bioinstruments, are enabling the collection and processing of larger amounts of

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biodata, thus enabling better understanding and newer discoveries. Although we have been able to record brain waves for a long time, the recent advances in machine learning and data-analytics are making it possible to interpret these waves more thoroughly, read their "messages" more clearly, and correlate them more directly with actions and behaviors.

Driven by these advances, we are already witnessing important strides toward exploring the complex wilderness of the human brain and mind. This past May, DARPA, the funding agency that is responsible for the advancement of research programs for the U.S. Department of Defense, launched an ambitious multimillion-dollar program in support of mind-control technologies. The program's objective is to develop solutions that enable the control of defense systems and swarms of drones through a soldier's thoughts and without requiring surgery [4]. Six research teams have been selected to receive funding under the so-called N3 Program, which stands for the Next-Generation Nonsurgical Neurotechnology Program. The main motivation of the N3 program is to reduce the latency (or delay) that exists between the moment a soldier decides on an action plan and the time it takes for his/her limbs and muscles to act by pressing control buttons or typing commands on a keyboard.

Some will question the devious reason behind the need for launching weapons at faster speeds, even to the point of spending millions of dollars on trying to reduce the action time by milliseconds. Others will argue in favor of such investments to enhance one's defense capabilities. Regardless of the argument that you are most comfortable with, my intention is to focus purely on the enabling science; namely, on the ability to use one's thoughts to control machines. It is not clear how successful these efforts will be. However, time and again, we have witnessed how similar ambitious projects in the past, driven initially by purely military considerations, have ended up leading to superb technological advances for society at large.

The most notable modern example is the Internet, which started as a military project in the mid 1960s called ARPANET (Advanced Research Projects Agency Network). It was funded by the U.S. Department of Defense. The purpose of the project was to develop technology that would enable a network of computers to communicate with each other and to store information in a decentralized manner. A network of this type would be more robust in the face of catastrophic events, such as a nuclear event during the years of the Cold War. We have come a long way since then, with the Internet today defining our modern times. While researching the history of ARPANET, I found the following passage very amusing on the Wikipedia page; it is extracted from [5, p. 9]. The reference is a 1982 manual for users at the MIT AI Laboratory instructing them on the use of their computer network:

"It is considered illegal to use the ARPANET for anything which is not in direct support of Government business … personal messages to other ARPANET subscribers (for example, to arrange a get-together or check and say a friendly hello) are generally not considered harmful … Sending electronic mail over the ARPANET for commercial profit or political purposes is both anti-social and illegal."

Contrast the instruction in the last sentence of this paragraph with the current state of affairs! Using the precursor of the Internet for commercial purposes was considered both "antisocial and illegal." At the time of this writing, Amazon.com, one of the largest commercial enterprises ever, has just commemorated 25 years of existence, having been launched on July 5th, 1994. This is only one example of the vast online world we live in today, besides email and messaging tools that we cannot live without! The practice of exchanging "friendly hellos" was considered "nonharmful" back then. Today, the practice has evolved into flooding our inboxes with messages for the most trivial reasons, apart of course from the relentless spamming. I love the short emails that say "Hi, can we have a brief chat by phone?" I have used them myself. Why not just pick up the phone? We are becoming mentally wired to using an electronic medium, perhaps because it is easier nowadays to reach people by email than by phone in an ever-interconnected and busy world. Given our hectic schedules, it is often a necessity to schedule beforehand a time to chat by phone, and we use emails to break through that barrier! The online world is changing our social behavior. Similar effects are likely to occur, and perhaps on a much more pronounced scale, once we start tinkering with our brains and minds! Be prepared.

Similar to what happened with ARPANET, whether successful or not, the recent DARPA efforts may similarly lead to important technological advances of great societal and clinical value. Advances in neurotechnology are likely to have an impact on computing, the consumer industry, and on the pharmaceutical industry. This is because a better control and understanding of the brain functions and its chemistry can suggest more effective drug systems, promote new forms of consumer neurotechnology, and even lead to new computing modalities. For example, the brain is recognized as a more efficient machine, consuming far less power (about 20W), than modern supercomputers (which consume close to 5–10MW). There are several ongoing efforts, including by companies like Intel and IBM, on neuromorphic computing and the design of neuro-chips that imitate the functionality of brain cells. These chips are also embedded with learning abilities [6]. Imagine the devices inside your machines becoming more powerful and wiser as they age based on experience!

Advances in neurotechnology will further lead to hybrid brain–machine interfaces to augment human capabilities and to assist with disabilities. There already exist prototypes of headsets that allow users to control electronic devices such as their TVs using thought commands [7]. Facebook is also apparently working on a brain–machine interface that would read people's thoughts and allow them to navigate and interact with an augmented reality environment in that manner alone, without the need for keyboards, remote controls, or gestures [8]. It is estimated that Facebook

has over 60 developers working on this technology alone. Just imagine how much more privacy users will give up if and when this Facebook interface becomes a reality!

In yet another recent development [9], researchers at the University of Washington demonstrated a setup where two individuals sitting in separate rooms can communicate clues through their thoughts to a third person in another room. The thought commands are meant to help the third individual move a falling block on a computer screen to the right or left in a Tetris-like game until it fits into the proper location on the bottom row. The third individual does not see the bottom row but only sees the falling block and deciphers the "mind" commands that arrive from the other two individuals. Advances of this type open up the possibility of communicating without language or gestures. They may also enable transmitting thought commands from one healthy individual to a patient.

We are often enamored by the wonders of technology, and gasp at demonstrations reading our thoughts. Yet, we need to remain vigilant and conscious of how technology is invading our personal space and altering our own humanity. Tinkering with the minds and brains of individuals can alter these individuals forever! Social norms and behavior will change; no question about that. Similar to what has happened with the online medium, we should avoid immersing ourselves uncontrollably into new technologies without considering the implications on our personal space, privacy, and behavior. We should approach advances of this magnitude with a mind of our own and have a more inquisitive approach. As the Spanish proverb goes, "A wise man changes his mind, a fool never."

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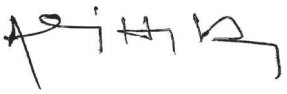

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