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## A Case for Computer-Brain Interfaces

Computers are growing smarter while humans are not. Raymond Kurzweil, futurist and inventor, says “technological progress happens exponentially, not linearly” (Grossman) because of a phenomenon called “the law of accelerating returns.” Succinctly, the design of every new generation of computers is aided by cutting-edge computers of the previous generations, which effectively compounds processing power upon itself. The human brain, to the contrary, is limited by biological factors. A recent study on human brain evolution by Michel Hofman of the Netherlands Institute for Neuroscience found that “the human brain lies 20-30% below the optimal... information processing capacity per unit time” (Hofman 387). However, he argues that “further enhancement of human brainpower... is an unrealistic biological option and must be discarded” in part because the brain would have to double in size.

While the human brain has nearly peaked its neural-processing limits, humanity is acquiring, storing and relying on computers to process vastly more information every year. This is due in part to the ubiquity of constantly connected mobile devices coupled with massive databases compiled by corporations and governments. The phenomenal influx of information these technologies are bringing has been dubbed “Big Data,” a major topic discussed this year at the World Economic Forum. A report titled “Big Data, Big Impact:” says: “The amount of data in the world is exploding... Researchers and policymakers are beginning to realize the potential for channeling these torrents of data

into actionable information...” (Vital 1). The report postures itself to identify the needs of low-income populations by performing data analysis on them, but Big Data can be used for virtually anything. The U.S. federal government recently announced \$200 million in funding toward Big Data research programs (Lohr) and since most major corporations have collected vast amounts of information about people who walk through their doors for decades, (Duhigg 1) they undoubtedly will want to capitalize on Big Data too.

With the human mind’s processing capacity nearly maxed out, and the world’s available information increasing with no end in sight, the maximum possible portion of the world’s knowledge that one mind can understand or use is virtually shrinking. “The Dark Side of Information,” a 2008 report on information overload says this is an unprecedented phenomenon:

The issue of quantity of information supplied has undergone a sea-change, relatively recently in terms of the history of the communication of recorded information. For most of this history, the issues (sic), or problem, has been the ability to find, or to provide, a sufficient quantity of useful information... It was so through the era of the hand-written manuscript, and equally so for most of the era of the printed book and journal... It is only in the nineteenth century, with the great expansion of professional and academic, as well as general, publication, that the modern form of overload begins to appear, with regrets that one can no longer keep up with the literature of one’s own subject. (Bawden 182)

The paper continues to say that the situation further changed in the 1990s; the adoption of the Internet meant that overwhelmingly large quantities of information could easily be found on almost any topic. As the complexity of the known world increased, the

knowledge required to be considered an expert in nearly any field vastly outpaced human memory, so people outsourced their information filtering to computers in the form of search engines and predictive algorithms (Bawden).

Unfortunately, the implications of this reach much farther than the simple segmentation of human expertise. Democracy requires, at its core, an informed electorate. Trends like exponential computing increase and Big Data mean effectively that even the most well intentioned citizens are growing less and less informed compared to their predecessors, as they outsource their information filtration to computer systems. In comparison with Hoffman, Bawden acknowledges the limitations of the human neural processing capacity, however his analysis alludes to a possible solution:

It may be argued that information overload is the natural and inevitable condition of the human species. There has been a consistent viewpoint suggesting that the issue is exaggerated, or even imagined... Our senses, particularly the visual sense, are able to handle a huge amount of input, and to identify significant patterns within it. The modern information environment, however, presents us with information in forms with which our senses, and prior experiences, are ill-equipped to deal. (Bawden 184)

By Bawden's invocation of the human brain's ability to handle complex visual stimuli, it can be extrapolated that the brain could better handle the huge amount of input from the modern information environment if it were to develop senses tuned to deciphering that information. This could occur naturally as humans evolve in this information-rich environment but it would likely take many generations.

This relative shrinking of the average human's grasp of the known world may not in and of itself pose a significant problem, but humans are not likely to remain the sole intelligence on Earth in the coming years. Humanity is already synthesizing rudimentary forms of intelligence in computers. For instance, a 2009 New York Times article that interviewed scientists concerned about advances in rudimentary artificial intelligence said: "a number of technologies as diverse as experimental medical systems that interact with patients to simulate empathy, and computer worms and viruses that defy extermination... could thus be said to have reached a 'cockroach' stage of machine intelligence" (Markoff). While the scientists brushed aside the notion of a super-intelligence springing from the Internet, they expressed concern about autonomous military robots and, notably, are planning to meet again to discuss the possibility of "the loss of human control of computer-based intelligences" (Markoff).

Many scientists think a general artificial intelligence—a synthetic intelligence that is self-aware and can make decisions about its livelihood; commonly known as A.I.—is nearing reality. Vernor Vinge, the acclaimed mathematician, computer scientist, and author said: "The best answer to the question, 'Will computers ever be as smart as humans?' is probably 'Yes, but only briefly.'" (Muehlhauser, 2) The outcome he alludes to is a prediction that many in the scientific and technology communities have dubbed the "intelligence explosion." If an A.I. running on computer hardware built another A.I. more intelligent than itself, Kurzweil's law of accelerating returns would ensure that, like all technological progress, each generation of A.I. would be exponentially more intelligent. Considering the exponential increase of available information and the possibility of

exponentially increasing artificial intelligence, it can be extrapolated that humans would do well to work past their own biological brain information processing limitations.

One method scientists are studying to enhance human cognition is through direct computer-brain interfaces (Kennedy). While the concept may seem outlandish, rudimentary brain prostheses have been in use for over forty years (Chivukula et al.). The computer-brain link in widest spread use is currently the cochlear implant, an electronic device that picks up sound waves and generates electrical impulses to simulate hearing in many deaf people. The first study to conclusively verify that human brains could translate electrical current applied to the inner ear as sound occurred in 1957, and the first speech processor to interface with an inner ear implant was developed in 1972. From then on, thousands of deaf or near-deaf people's lives have been improved by synthetic hearing. It started as a relatively rudimentary device designed to pick up radio signals from a very close transmitter and convert them into electrical impulses for the inner ear to interpret as sound. The technology has evolved since then, and now people with completely damaged inner ears are able to have devices implanted directly into their brain stems to allow a degree of hearing (Møller 8).

More recently, several formerly blind people have benefitted from rudimentary visual implants (Restak 205). Most of them are composed of a small camera mounted into a glasses frame and a tiny circuit implanted into the retinal surface of the non-working eye. They are able to see shapes, navigate rooms, and one patient was able to drive a car around a parking lot immediately after surgery. At least seventeen separate projects worldwide are currently working on new visual implants. These two technologies—auditory and visual prostheses—are examples of ways that brains can

potentially receive other information, but to be able to fully interact with a computer, a brain also needs to transmit information to computers. There are a variety of different technologies currently being developed that may facilitate this. Highly specialized external brainwave scanners such as fMRI machines have been used in medical facilities to analyze anomalies in different brains, and even map individual thought processes for years. Now, several companies are selling consumer products for as little as \$300 to be worn on the head and used to control computers and phones with simple thoughts (Le).

Another class of technologies being studied are implanted computer interfaces that monitor portions of the nervous system and brain directly. A group at Case Western Reserve University has developed the CWRU-VA, an implanted neuroprosthetic which receives signals from a quadriplegic patient's brain, bypasses their damaged spinal cord, and stimulates the patient's own muscles. (Rhode, 266) That the device can control an individual's own muscles is remarkable, but perhaps more incredible is the direct neural link the devices uses to understand the patient's intentions. Philip Kennedy, a neuroscientist and founder of Neural Signals, a brain-interface research center, has implanted other types of neuroprostheses. In 2004, his team fitted a sensor into the speech-motor cortex of Erik Ramsey, a patient almost totally paralyzed, and unable to speak on his own. They connected the sensor to a speech synthesizer, and Ramsey has learned to first produce sounds, and then effectively talk through it using his mind. (Ramsey, 25)

In a 2011 interview with the New York Times, computer-brain interface researcher Gerwin Schalk described problems that humans have interfacing with computers: "We're always interested in doing things faster... I remember the transition to

an electric typewriter. We're addicted to speed. But obviously the way we communicate with computers is rather comical. The way we interact with this blazing fast machine is to poke at it with a finger" (Kennedy). He works with epileptic patients that have already been fitted with an electrocorticographic brain implant to treat their seizures. His patients are able to play simple computer games like Pong using their interfaces and send simple commands to the computers by thinking about actions like moving their tongue. Schalk's goal is to teach the computer interfaces to respond to natural language thought, instead of spoken natural language. In order to do that though, scientists like him need a far more robust understanding of how the human brain processes information and generates thoughts.

One research group called the Blue Brain Project is working to simulate entire mammal brains, and eventually human brains. Henry Markram, the lead researcher at the project, anticipates that a "detailed, functional artificial human brain can be built within the next 10 years" (Markram). Once detailed brain simulations are a reality, scientists will be able to build a new generation of brain implants that are optimized for specific types of information sharing, like language. Kennedy says that Schalk proposes working on "a kind of Esperanto for man to converse with machine" (Kennedy) in anticipation of the new implants. Kevin Warwick, Professor of Cybernetics at the University of Reading is working with his students to study another method of routing information into the brain: transforming natural human senses into new inputs for digital stimuli (Warwick). He and his students have implanted magnets into their fingertips, which are vibrated by electromagnets in response to ultrasonic proximity sensors and infrared heat sensors worn on the body. This allows them to literally feel the distance to an object or an object's heat

remotely. The fact that all of these artificial input and output devices work at all, even with their varying degrees of success is testament to the human brain's plasticity—its ability to remold itself in response to new stimuli.

These and other emerging technologies will continue to provide more direct routes of interaction between human brains and computers. If humanity continues to acquire, store, and process Big Data, which it likely will, these technologies will be needed to interact with the vaster and vaster quantities of information to truly stay informed. Any emergence of an A.I. at human intelligence or above will greatly amplify this need, and the future of biological humanity will depend on the evolution of human brains and computers side-by-side.



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