UNDERSTANDING THE COMPLEXITY OF THE HUMAN BRAIN

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INTRODUCTION

For several years, scientists, engineers, and computer scientists alike attempted to imitate the brain's functions without paying much attention to the actual brain. Recently, it has proved successful to instead "reverse engineer" the brain. This essentially means that scientists are trying to understand the brain and model newer technology after it [1]. One application of reverse engineering the brain is creating technology that replaces or assists a function of the brain. One example of this technology is a brain implant. I chose to discuss brain implants because of their vast potential for helping those that suffer from neurological diseases/disorders, paralysis, or neurological trauma. There are many proponents that share this view, however, there are a select few that find these implants unethical, because it allows man to "play God." While I do understand these complicated concerns, the implants' potentials to solve medical problems, which are outlined in this paper, outweighs the concerns of opponents. One specific medical problem these implants can solve is blindness. By studying the brain and imitating its makeup, scientists have successfully created retinal implants that return partial vision to people suffering retinal deterioration caused blindness. I have a personal connection to this application, because of my grandfather who suffers from blindness, however, the possibilities for the implants are endless.

THE IMPORTANCE OF REVERSE ENGINEERING THE BRAIN

The Power of the Brain

Reverse engineering holds an unfathomable amount of possibilities. This is because the brain is infinitely complex. The brain is composed of eighty-six billion neurons, the cells that compose the brain. Neurons are long cells that interconnect in extremely complex patterns to move electric signals through the brain. Each neuron has a number of dendrites on one end and axon terminals on the other [2]. A dendrite on one neuron connects with an axon terminal of another neuron. This connection is called a synapse. Within a synapse, ions (charged atoms) called electron transmitters are moved between neurons in order to transfer an electrical signal, sometimes with speeds approaching 270 miles per hour [2]. Ph.D. Mario Garret of *Psychology Today* states that there are over 1,000 to 10,000 synapses per neuron, and this results in over 125 trillion synapses in the human brain; more than the number of stars in our galaxy. These synapses are constantly changing as the brain learns. This changing allows the brain to keep adapting to its environment and predict the world around it [2].

By harnessing a miniscule amount of this structure and applying it to human technology, humans could start to imitate these beautiful functions of the brain. If computers were able to process multiple streams of complicated information like a brain, computers could be faster [1]. If technology could learn similar to a brain, artificial intelligence could be possible. This is what the future looks like.

What Reverse Engineering the Brain Means for Medicine

Understanding the brain by means of reverse engineering would not only allow us to better human technology. It would also give scientists, engineers, and doctors better means to solve natural issues with the brain itself [1]. This is important to me because I am an aspiring bioengineer, and this could be something I work with as a career. Neurological diseases are devastating, and, due to the complexity of the brain, treatment is often not very effective. For example, Alzheimer's disease burdens millions of people, and treatment is scarce. It is not only horrible for the victim of the disease, not being able to remember basic things that once made them so full of life, but also the victim's family. From personal experience, I can attest to how terrible it can be to see someone you love become a shell of the person they used to be. They might not even be able to remember your name. The fact that there are billions of neurons in the brain makes treatment of this mental disease so difficult [2]. There are several other diseases and disorders that are so hard to treat due to the lack of understanding of the brain: Parkinson's disease, epilepsy, cerebral palsy, amnesia, schizophrenia, dementia, multiple sclerosis, etc. Similar to a mental disease, losing a sense is very difficult to treat due to the complexity of the brain. Going blind, for example, can have huge negative effects on a person's life, such as not being able to get around by yourself, because of humans' large dependence on sight. The interaction between ocular nerves and the brain is so advanced that the treatment of blindness is miniscule [3]. The lives of the victims of these issues could be greatly improved by technology generated by reverse engineering the brain. This would create a far more accurate understanding of neurological makeup, which would lead to the development of effective treatment. This is why it is so important to reverse engineer the brain [1].

BRAIN IMPLANTS

What Brain Implants are and How They Work

One type of technology that has been developed and improved by the reverse engineering of the brain is technology that assists the brain. If one part of the human nervous system is not working correctly, modern technology can be used to help or replace it. I believe this technology can effectively relieve those suffering from neurological issues described previously. The vessel that is used to do accomplish this is a brain implant.

A brain implant mimics functions of the brain. Each one is unique, however, the basic premise for how they work is similar. The brain communicates with itself, and to the rest of the body, with electronic signals [4]. Neurons do this by transferring electronically charged particles, such as potassium ions, between them so relay signals [5]. When a brain "thinks" a series of electronic signals moves in a measurable and consistent way. These tiny electronic signals can be measured with electrodes placed on the surface of the brain. They can then be amplified and decoded by a computer program into certain actions, like moving a robotic hand [6]. Conversely, if an external object, for example a microphone, recorded some stimuli, in this case sound, a computer could translate this into a series of tiny electronic signals that could be relayed to the brain [5]. This may sound simple, however the innerworkings are very complicated. How large are the signals, how many are there, and what do they mean? These are all questions that need to be answered in order to make these implants feasible [5]. However, this can be done. By equipping a brain with electrodes, scientists can discover which part of a brain controls a certain function [6], the amplitude of the electric signals, and the spacing between the signals. The signals' patterns of size and frequency dictate the outcome of that thought [5]. Memories, too, can be translated into pulses of electric signals. Theodore Berger, a biomedical engineer at the University of Southern California, describes a memory as "[…] a series of electrical pulses over time that are generated by a given number of neurons. That's important because you can reduce it to this and put it back into a framework." This means that a memory can be broken down into a readable series of signals [5]. This creates numerous opportunities. For example, these patterns could be recorded, and stored, by a silicon chip implant placed in the brain. This has not occurred in humans yet, but it has been done with animals. Human trials are predicted to occur soon, according to Berger. This could really help those who suffered from dementia, Alzheimer's, or other memory issues, because it could give them the ability to store memories again [5]. Berger states "If I can give them the ability to form new long-term memories for half the conditions that most people live in, I'll be happy as hell, and so will be most patients."

How Brain Implants Can Be Improved by the Reverse Engineering of the Brain

By studying the brain and modeling technology after the it, the technology created can be used more synonymously with the brain. If the implants that have been created now are improved so that they closer resemble the brain, they will perform similarly to the brain, making the two more compatible [6]. For example, take an implant that relays a signal from a brain to a robotic arm. The robotic arm will work better if the number of signals received by the brain is closer to the number of signals a real arm receives. Currently, these numbers are distant, making the prosthetics clumsy [6]. By studying how a normal, fully biological brain, works, these numbers can become closer, making the implant's effectiveness increase. The technology is getting more and more similar to natural systems, and will continue to get better for years to come, as engineers focus on reverse engineering the brain.

HOW BRAIN IMPLANTS CAN HELP PATIENTS

Although memory boosting implants are on the horizon, there are implants that exist now that benefit those suffering from neurological issues. For example, cochlear implants have helped 300,000 people around the world that suffered from hearing loss [4]. A device converts sound to brain signals that can be read by the brain. An implant has also been built that sends electronic pulses to the motor control portion of the brain that helps prevent the tremors from Parkinson's disease. Additionally, some implants decode the signals of the motor control part of the brain to computer code that controls a robotic prosthetic [4].

One specific occurrence of brain implants restoring something lost is their use in restoring sight to patients that suffered from hereditary retinal deterioration. German scientists by the names of Ziad M. Hafeda, Katarina Stinglb, Karl-Ulrich Bartz-Schmidtb, Florian Gekelerc, and Eberhart Zrennera, tested the effectiveness of a retinal implant to restore sight [3]. They placed a chip in the subjects' eyes that essentially replaces photoreceptors in the eye with light-sensitive photodetectors. These photodetectors are light-sensitive elements, and are connected to amplifiers and electrodes. When light hits the photodetectors, it is amplified and converted into electric signals that stimulate the vision area of the brain [3]. The results of the tests with this implant are spectacular. Two male subjects rendered blind by a hereditary disease were asked to partake in an experiment where they would have one of these implants placed in their eye. They sat in a dark room and were asked to fixate their eyes on a white circle when it appeared. Surprisingly, the subjects were able to fixate their eyes on the circle quite well (within 2 degrees of accuracy), after having this implant placed in their eye [3]. These implants allowed two men who, in the words of the scientists "had a significant disability with large implications on quality of life," see again. Being able to give someone who has suffered through a neuro issue their life back is capable with these implants.

Potential Issues with Brain Implants

The implants discussed above are in their infancy. The "language" of the brain, with well over 100,000 miles of neurons, is so unfathomably complicated. Since there are trillions of synapses it would take millions of years to map them all. For this reason, the implants will only be able to mimic a very small portion of the brain's function. The implants can be invasive, as well, when they are placed in the brain. They can cause scar tissue and trigger the immune system. If the body rejects the foreign body, the results could be catastrophic. Lastly, some people believe that the implants "play God" by potentially altering personality and human identity [4].

Although the brain is very complicated, the areas the implants stimulate, or receive stimulation, are small compared to the rest of the brain [5]. By focusing in on these specific parts of the brain, learning the patterns of electric signals in the brain is feasible over time. Scientists are also working on using biocompatible materials when building implants. Buddy Ratner of the University of Washington states that biocompatibility is "the ability of materials to locally trigger and guide normal wound healing, reconstruction, and tissue integration." The U.S. spends about 300 billion dollars on generating biocompatible materials a year, so making these implants out of biocompatible material is very doable [7].

On a separate note, these implants are only able to alter basic parts of the human brain. Personality, learning behavior, and "human essence" are such complicated systems within the brain that I do not believe that people should be worried about the human identity as far as these brain implants go. The technology is so new and the brain is so complicated that the implants will be applied to simpler things, like restoring vision, for a long time to come. However, if that does not comfort some people, the Human Brain Project states that the project understands that altering "human identity" would have drastic social effects, and, in turn, says if a part of the project deals with human identity, the project will be regulated [8]. Overall, I believe allowing a blind person to see, an Alzheimer's victim to remember, a Parkinson's victim to stand, and a paraplegic to move, outweighs these risks.

CONCLUSION

The human brain is a vastly complicated system that we still do not know much about. By studying the brain and designing technology around it, computers could improve, artificial intelligence could be created, and problems with the brain could be remedied. Brain implants, a newer technology, could benefit greatly by reverse engineering of the brain. By making them more similar to the brain, they could be more in sync with the brain, making them more effective. These brain implants could help people suffering from various brain issues such as Alzheimer's, and also people suffering from loss of a sense, such as vision. Since the number of people suffering from brain issues is so significant, the development of these implants should be, and will be, a significant priority of the future, and I hope to be part of it as an engineer.

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ACKNOWLEDGMENTS

I would like to thank my mother and father, Nicole and Michael Shulock, for putting me in the position to take this Engineering 0011 class. I would also like to thank my roommate Shloke Nair for proofreading this paper.