NEUROPROSTHETICS: THE MIND AND BODY AS ONE

Madison Brennan (mbb62@pitt.edu)

OF MIND AND BODY

The loss of one or more limbs is an extremely debilitating impact on someone’s life. According to an article published by the Centers for Disease Control and Prevention, approximately 1.9 million people are living with limb loss in the United States [1]. In order to restore basic functionality to these amputated parts of the body, prosthetics have been custom produced to replace the former limbs. Throughout the centuries, prosthetics have evolved to become more efficient at returning an amputee to the lifestyle they once had. The most recent advancement in the prosthetic field has been the testing and development of neuroprosthetics. A neuroprosthetic is a device that transmits the inputs and outputs of the body’s nervous system which allows the amputee greater control over the movement of a prosthetic. I believe that if engineers focus their efforts on neuroprosthetics, they will be able to greatly improve the mobility and lifestyle of those who have suffered from a disabling injury such as a spinal cord injury. Currently, neuroprosthetics are being tested here at the University of Pittsburgh and are yielding positive results. These significant advancements of the technology are extremely important to me because I am highly considering entering into this field in the future. Neuroprosthetics are an innovation unlike anything else and are paving a way to the future of neuroengineering which is why I strongly believe engineers should direct their efforts towards the development of this new technology.

WHAT ARE NEUROPROSTHETICS?

Although prosthetics have been an effective way to restore functionality to amputated areas of the body, they limit the feelings of control and sense of touch that the amputee once had. In order to improve upon prosthetics and rectify this flaw, neuroprosthetics are being developed and tested by scientists across the globe. Neuroprosthetics reestablish motor function to the disabled through the use of functional electrical simulation (FES). According to an article published in the Journal of Spinal Cord Medicine, functional electrical simulation, “uses electrodes to stimulate muscles or nerves to produce muscle contraction” [2]. This proves to be difficult, however, due to the change that some of the muscle tissue undergoes from disuse and loss of nerve supply as a result of injury. Therefore, the muscles that have remained intact must be trained to become more “fatigue resistant” [2]. Many forms of electrodes have been tested for FES but the two most effective have been electrodes that require implantation and surface electrodes [2]. Surface electrodes, compared to those that are implanted, are often easier to operate and relatively less expensive, but demand some level of skill for placement. On the other hand, implanted electrodes have the ability to stimulate deeper muscles and do not require as much electrical charge [2]. Despite the types of electrodes, both methods are able to transmit signals from the brain in order to restore some degree of function to those with serious motor disabilities.

In order to transform thoughts into actions, the electrodes must decode signals from the brain. A brain-machine interface (BMI) is one way in which brain waves are transmitted to an external device. An article published by The Scientist magazine explains that they do so by being able to, “record the electrical rhythms resulting from complex interactions of neurons and support cells such as glia, averaged over several centimeters of the cortex” [3]. Once the frequencies in the cortex are detected, a person’s intended actions can be interpreted from the data. After this intention is identified, the computer is able to display it through a certain output [3]. Therefore, amputees will be able to better manipulate the prosthetics since they will be reciprocating their intentions through motion. Along with allowing a greater amount of control over the prosthetic, the electrodes also provide the sense of feeling through electrical stimulation. When trauma occurs to a part of the body, the triggers that activate the sense of touch from the brain are completely damaged. Through new neuroprosthetic technology, however, amputees are able to regain those sensations. This is done by “patterns of electric signals that are communicated by a computer to nerves in the arm and to the brain” [3]. This is an extremely significant technological advancement because it allows for amputees to feel as though complete functionality of their lost limb has returned. As a result of these abilities of neuroprosthetics, those who have
suffered from debilitating injuries will be able to return to the more functional lifestyle they once had.

THE IMPACT OF NEUROPROSTHETICS ON TETRAPLEGIA

In just the past few years, neuroprosthetics have made great improvements in the field of bioengineering, but more specifically, in prosthetics. One area that really benefits from this new technology is the treatment of tetraplegia. According to the American Association of Neurological Surgeons, tetraplegia is a condition in which the ability to move all extremities is lost as a result of injury to the spinal cord [4]. Two areas of the body that are significantly impacted by tetraplegia are the arm and hand. Since the injury to the spinal cord completely damages all connection between these parts of the body to the brain, regular prosthetics would not be an effective solution. Therefore, neuroprosthetics are being utilized due to their ability to transmit signals from the brain to the prosthetic and restore the patient’s sensation of touch [5]. As a result, in order to restore some functionality to these elements of the body, robotic arms utilizing neuroprosthetic technology are being developed and administered [5].

On the surface, it may seem as though grasping and lifting an object are not very difficult tasks. When researching the mechanics behind these motions, however, it is apparent of how much information must be processed in order to complete them effectively. Therefore, neuroprosthetics to treat disabled arms as a result of tetraplegia have been developed in order to process material just as though the injury had never occurred. Some of the critical information includes the, “contact location, contact pressure, and contact timing” when grasping an object [5]. It is extremely valuable to incorporate these features because, as a result, this neuroprosthetic technology is allowing those with tetraplegia to gain a greater sense of natural control over the robotic arm. Though all features of this device are important, the most significant function of neuroprosthetics is to allow the injured to regain their sense of touch.

By restoring the sense of touch to those who have tetraplegia, their ability to manipulate the neuroprosthetic arm will increase. This means that the functions of grasping and lifting will become more facile since the amputee will be able to acquire more information about the object. Sliman Bensmaia, a neuroscientist from the University of Chicago, express his opinion on the matter by stating, “If you want to create a dexterous hand for use in an amputee or a quadriplegic patient, you need to not only be able to move it, but have sensory feedback from it” [6]. This is an extremely significant statement because it captures the main purpose of the neuroprosthetic arm for those with tetraplegia. By incorporating the sense of touch into the robotic arm, it will be able to embody more human like qualities. As a result, the user will become more comfortable with the neuroprosthetic and begin to feel as though it is their actual limb [5].

advancement in prosthetics is extremely remarkable and signifies where the future of neuroprosthetics is headed. Before the field of neuroprosthetics can take the next step, however, improvements must be made to the existing devices.

RESEARCH OF NEUROPROSTHETICS

To improve upon the functionality of the neuroprosthetic arm research projects are being conducted in order to identify and rectify its flaws. For example, at the University of Pittsburgh and Carnegie Mellon University, research has been and continues to be completed regarding the development of neuroprosthetics. Recently, John E. Downey, a graduate student at the University of Pittsburgh, along with other colleagues on his team, decided to test the effectiveness of brain-machine interfaces (BMIs) on neuroprosthetic arm performance. Two test subjects were selected for this study, one of whom had suffered from tetraplegia [7]. For this experiment, the subjects were put through the Action Research Arm Test (ARAT) in order to test a robotic arm during a series of reaching and grasping tasks [7]. This test requires the subjects to utilize the neuroprosthetic arm in order to transfer different sized cubes from one location to another. The ARAT was run in two trials, shared and unshared control, for each task assigned. While unshared control is just the use of BMI, shared control combines the BMI system with “vision-guided autonomous robotic control” [7]. This way, the BMI can recognize the subject’s intent while also allowing the computer to intervene during more challenging tasks. It was concluded from this experiment that neuroprosthetics utilizing shared control were much more successful than those solely using BMIs. Both subjects felt that, “Movements made using shared control were more accurate, more efficient, and less difficult” [7]. As a result of these findings, further research will be completed on the effectiveness of shared control on neuroprosthetics. In the future, this method could be implemented in all neuroprosthetics if it proves to be the most efficient design. Though great advancements have already been made upon neuroprosthetics, more improvements can be made upon these products.

THE NEED FOR ENGINEERS TO BECOME INVOLVED

Altogether, being able to improve prosthetics in order to become more functional has various benefits, and I believe that focusing research towards neuroprosthetics is the most effective way to do so. In the past, prosthetics were designed to provide stability to the amputated areas but were not efficient in restoring basic mobile and sensory functions to those who were living with a debilitating injury. Neuroprosthetics are an advancement upon prosthetics which allows for greater control of the movement and sensation of artificial limbs. If engineers were to further study the abilities
of neuroprosthetics, amputees could, one day, fully return to the lifestyle they once had. For example, if someone had lost all functionality of their arms, they would no longer be able to clean, drive, or participate in the majority of recreational activities. The primary role of an engineer is to benefit society so engineers should feel obligated to become involved with this research. Though significant levels of success have already been achieved through the testing of neuroprosthetics, there still remains a long road ahead. If engineers focus their attention and resources to neuroprosthetics, it will shorten the time needed to design the most efficient neuroprosthetic prototype and return amputees back to their former jobs, activities, and overall lifestyle.

THE SIGNIFICANCE OF NEUROPROSTHETICS TO ME

When entering the Swanson School of Engineering, I was unsure of which discipline of engineering I wanted to pursue. As I researched more regarding the certain majors offered at the University of Pittsburgh, I came to the conclusion that bioengineering was the best fit choice for me. While researching bioengineering, I explored the various types of work that one can complete after receiving a collegiate degree in the field. One area of work that seemed exceedingly intriguing to me was the development of neuroprosthetics. I find prosthetics to be interesting because they play such a significant role in the improvement of people’s lives, specifically those enduring a debilitating injury. Though I have no personal connection to someone who has a prosthesis, I do feel as though I am impacted by the people who utilize prosthetics who I witness day-to-day. When I see someone who lacks motor function in parts of their body such as their arms, legs, or neck, I immediately feel sympathetic towards their situation. As a result, I want to be able to make a positive impact on their lives in my future career. Working in the development of neuroprosthetics will allow me to do so because I will be directly involved in the improvement of prosthetics. Being able to formulate methods that will increase the capability of motion and sense of touch in prosthetics will greatly improve the lifestyle of those who are disabled. Therefore, I believe that neuroprosthetics are valuable not only because of their significant impacts on the field of prosthetics but also because they will assist me in achieving my goal to improve the lives of those who are suffering from disabling injuries.

THE OVERALL IMPACT

Ultimately, neuroprosthetics are a significant improvement upon prosthetics that have been regularly utilized by amputees in the past. These neuroprosthetics are making great advancements due to their ability to efficiently restore functionality back to those enduring a disabling injury through the integration of brainwaves and computer technology. As research and testing of this new technology continue, more developments will be made within the field of neuroprosthetics. It is imperative that engineers focus their efforts into the advancements of this technology because in the future it will be able to completely return amputees to the way of life they were once familiar. In my future engineering career, I hope to be directly involved with the field of neuroprosthetics in order to exercise my biomedical engineering knowledge to assist those who need to rely on prosthetics to go about their everyday lives.

SOURCES


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