FUNCTIONALITY OF COGNITIVE NEUROPROSTHETICS FOR MECHANICAL PROSTHETIC INTEGRATION

Background

Prosthetic technology has been around for millennia, but in recent years it has greatly improved in functionality and similarity to biological hands. The next step being taken is connecting prosthetics with the human brain using a device called a Brain-Computer Interface (BCI). When BCIs are connected to special prosthetic devices, called cognitive neuroprosthetics, they allow the user to control the prosthetic movements with their mind.

The BCI can also, to a limited degree, return sensation to the user by sensing information from the environment with sensors on the prosthetic and stimulate the brain to give the user a sensation of tactile feedback. This technology is especially useful for patients who are not able to use myoelectric prosthetics due to a disability.

(Above) A mechanical prosthetic device used in several studies on cognitive neuroprosthetics. This device was connected to computers that communicated wirelessly with the BCI implanted in participants’ heads. Included are the various degrees of freedom that the prosthetic exhibits.

Ethics

Informed consent
• With any scientific research, researchers must inform participants and gain their consent.
• BCI electrodes can potentially alter the ability to consent, depending on electrode location
• Extra measures must be taken to evaluate participant eligibility, inform them, and obtain their consent.

Lack of Benefit
• Currently, cognitive neuroprosthetics do not deliver natural-feeling functionality, which questions the usefulness of neuroprosthetic research.
• However, many participants are happy to help future generations despite lack of individual benefits.

Psychological Health Concerns
• Participants may feel like they lose their identities as part of a neurodiverse culture.
• It is a researcher’s duty to inform participants and warn them of this feeling, and ensure they are willing to alter this identity.

Neuroprosthetic Studies

Tactile Feedback in Primates
• At the California Institute of Technology, a primate implanted with a neuroprosthetic was studied to tell whether physical sensations could be replicated by the neuroprosthetic. A computerized arm was moved using the signals the prosthetic captured from the brain, and the electrical signals were sent back when the arm touched an digital object. The primate showed distinct signs of being able to feel the object when the simulation came into contact with it.

Prosthetic Limb use in Primates
• A trial conducted at the University of Pittsburgh implanted two primates with the neuroprosthetics to control a mechanical arm. These primates were able to successfully control the 7 degrees of freedom, and were trained to use the system by having the arm being control semi autonomously, with more control given to the primate after sufficient control of the limb was shown.

Human Implementation of Neuroprosthetic Systems
• A paralyzed woman implanted with a neuroprosthetic was shown to be capable of controlling 10 degrees of freedom of a prosthetic arm through a 236 day trial. This marked the first time a human was shown to control a prosthetic through such a system, further showing the possibility of neuroprosthetic systems having a true use in the medical field.

Product Sustainability

Marketing
• There is a very small market for neuroprosthetics, so marketing campaigns are ineffective.
• US regulations restrict commercial use of neuroprosthetics.

Reimbursement
• Neuroprosthetics are relatively new, and many insurance policies will not reimburse patients.

Production
• Research prototypes are produced on a case-by-case basis.
• Manufacturing products like that is more expensive and inefficient when compared to mass production.
• Manufacturers will only be able to have sustainable production once neuroprosthetics leave developmental stages and begin commercialization.

The Future

The first step into the future for cognitive neuroprosthetics is eliminating the limitations that the prosthetics currently have. For example, one issue is that mechanical hands do not move as fluidly as human hands, causing damage to the hand or the object it is trying to manipulate if everything is not perfectly aligned. However, as the processes that return sensation to the user increase in efficiency and accuracy, this problem can be eliminated.

Additionally, as BCI technology evolves, more non-invasive BCI products will be available for industrial use. While not as useful to amputees due to slower processing speeds, non-invasive BCI could be used to remotely control robots involved in dangerous fields, such as mining, search-and-rescue, firefighting, and other areas where there is risk of radiation exposure or other physical harm. As the technology develops, it will overcome its limitations and be a more useful, sustainable, and widespread technology that everyone can benefit from.

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