Neuroprosthetics

Neuroprosthetics, also known as neural prosthetics or brain-computer interfaces (BCIs), are devices that aim to restore or enhance the functionality of the nervous system by connecting artificial components directly to the brain, spinal cord, or peripheral nerves. These devices establish a communication pathway between the nervous system and external devices, allowing for bidirectional information transfer.

Neuroprostheses can be used to assist individuals with neurological disabilities or impairments by providing alternative ways to interact with the environment. They can also be used for research purposes to study neural functions and brain-machine interactions.

Here are some examples of neuroprostheses and their applications:

Brain-Computer Interfaces (BCIs): BCIs are devices that enable direct communication between the brain and external devices, such as computers or robotic limbs. They can be used to help individuals with paralysis or severe motor disabilities control computers, assistive technologies, or robotic limbs using their brain signals.

Cochlear Implants: Cochlear implants are neuroprosthetic devices used to help individuals with severe hearing loss or deafness by bypassing damaged parts of the inner ear and directly stimulating the auditory nerve, allowing them to perceive sound.

Retinal Implants: Retinal implants are neuroprosthetic devices designed to restore partial vision in individuals with certain types of blindness. These implants stimulate the retina's remaining cells to create visual perceptions.

Deep Brain Stimulation (DBS): DBS involves surgically implanting electrodes into specific regions of the brain to regulate abnormal neural activity and treat conditions like Parkinson's disease, essential tremor, and dystonia.

Functional Electrical Stimulation (FES): FES uses electrical stimulation to activate paralyzed or weakened muscles, allowing individuals with spinal cord injuries or other neuromuscular disorders to regain some level of movement.

Neural Recording Devices: These devices are used in research to record electrical signals from individual neurons or groups of neurons, providing valuable insights into brain function and neural activity.

The development and application of neuroprostheses represent a promising field that can significantly improve the quality of life for people with neurological disabilities. As technology advances, these devices are expected to become more sophisticated and widely accessible, opening up new possibilities for medical treatments and research in neuroscience. However, ethical considerations, data privacy, and long-term safety remain important aspects to address as the field continues to evolve.

Neuroprostheses are also devices that use electrodes to interface with the nervous system and aim to restore function that has been lost due to spinal cord injury.

The composition of tissue obstructing neuroprostheses devices is largely composed of inflammatory cells with a significant astrocyte component.

In recent years, the majority of the population has become increasingly reliant on continuous and independent control of smart devices to conduct activities of daily living. Upper extremity movement is typically required to generate the motor outputs that control these interfaces, such as rapidly and accurately navigating and clicking a mouse, or activating a touch screen. For people living with tetraplegia, these abilities are lost, significantly compromising their ability to interact with their environment. Implantable brain computer interfaces (BCIs) hold promise for restoring lost neurologic function, including motor neuroprostheses (MNPs). An implantable MNP can directly infer motor intent by detecting brain signals and transmitting the motor signal out of the brain to generate a motor output and subsequently control computer actions. This physiological function is typically performed by the motor neurons in the human body. To evaluate the use of these implanted technologies, there is a need for an objective measurement of the effectiveness of MNPs in restoring motor outputs. Sawyer et al. propose the concept of digital motor outputs (DMOs) to address this: a motor output decoded directly from a neural recording during an attempted limb or orofacial movement is transformed into a command that controls an electronic device. Digital motor outputs are diverse and can be categorized as discrete or continuous representations of motor control, and the clinical utility of the control of a single, discrete DMO has been reported in multiple studies. This sets the stage for the DMO to emerge as a quantitative measure of MNP performance [1)].

The emerging field of neuroprosthetics is focused on the development of new interventions that will be able to restore some lost neural function by selective electrical stimulation or by harnessing activity recorded from populations of neurons. As more and more patients benefit from these approaches, the interest in neural interfaces has grown significantly and a new generation of penetrating microelectrode arrays. [2)].

A major challenge these systems face is robust performance, particularly with aging signal sources.

The aim in this study was to develop a neural prosthesis that could sustain high performance in spite of signal instability while still minimizing retraining time. Approach. We trained two rhesus macaques implanted with intracortical microelectrode arrays 1-4 years prior to this study to acquire targets with a neurally-controlled cursor. We measured their performance via achieved bitrate (bits per second, bps). This task was repeated over contiguous days to evaluate the sustained performance across time. Main results. We found that in the monkey with a younger (i.e., two year old) implant and better signal quality, a fixed decoder could sustain performance for a month at a rate of 4 bps, the highest achieved communication rate reported to date. This fixed decoder was evaluated across 22 months and experienced a performance decline at a rate of 0.24 bps yr(-1). In the monkey with the older (i.e., 3.5 year old) implant and poorer signal quality, a fixed decoder could not sustain performance for more than a few days. Nevertheless, performance in this monkey was maintained for two weeks without requiring additional online retraining time by utilizing prior days' experimental data. Upon analysis of the changes in channel tuning, we found that this stability appeared partially attributable to the cancelling-out of neural tuning fluctuations when projected to two-dimensional cursor movements. Significance. The findings in this study (1) document the highest-performing communication neural prosthesis in monkeys, (2) confirm and extend prior reports of the stability of fixed decoders, and (3) demonstrate a protocol for system stability under conditions where fixed decoders would otherwise fail. These improvements to decoder stability are important for minimizing training time and should make neural prostheses more practical to use [3].

1)

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2)

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3)

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