Neuroprosthetics

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It has been suggested that *Brain implant* be merged into this article. (Discuss) *Proposed since October 2015.*

This article's **tone or style may not reflect the encyclopedic tone used on Wikipedia**. See Wikipedia's guide to writing better articles for suggestions. *(August 2011)*

Neuroprosthetics (also called **neural prosthetics**) is a discipline related to neuroscience and biomedical engineering concerned with developing neural prostheses. They are sometimes contrasted with a brain–computer interface, which connects the brain to a computer rather than a device meant to replace missing biological functionality.

Neural prostheses are a series of devices that can substitute a motor, sensory or cognitive modality that might have been damaged as a result of an injury or a disease. Cochlear implants provide an example of such devices. These devices substitute the functions performed by the ear drum and stapes while simulating the frequency analysis performed in the cochlea. A microphone on an external unit gathers the sound and processes it; the processed signal is then transferred to an implanted unit that stimulates the auditory nerve through a microelectrode array. Through the replacement or augmentation of damaged senses, these devices intend to improve the quality of life for those with disabilities.

These implantable devices are also commonly used in animal experimentation as a tool to aid neuroscientists in developing a greater understanding of the brain and its functioning. By wirelessly monitoring the brain's electrical signals sent out by electrodes implanted in the subject's brain, the subject can be studied without the device affecting the results.

Accurately probing and recording the electrical signals in the brain would help better understand the relationship among a local population of neurons that are responsible for a specific function.

Neural implants are designed to be as small as possible in order to be to minimally invasive, particularly in areas surrounding the brain, eyes or cochlea. These implants typically communicate with their prosthetic counterparts wirelessly. Additionally, power is currently received through wireless power transmission through the skin. The tissue surrounding the implant is usually highly sensitive to temperature rise, meaning that power consumption must be minimal in order to prevent tissue damage.[1]

The neuroprosthetic currently undergoing the most widespread use is the cochlear implant, with approximately 100,000 in use worldwide as of 2006.[2]

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History [edit]

The first known cochlear implant was created in 1957. Other milestones include the first motor prosthesis for foot drop in hemiplegia in 1961, the first auditory brainstem implant in 1977 and a peripheral nerve bridge implanted into the spinal cord of an adult rat in 1981. In 1988, the lumbar anterior root implant and Functional Electrical Stimulation (FES) facilitated standing and walking, respectively, for a group of paraplegics.[3]

Regarding the development of electrodes implanted in the brain, an early difficulty was reliably locating the electrodes, originally done by inserting the electrodes with needles and breaking off the needles at the desired depth. Recent systems utilize more advanced probes, such as those used in deep brain stimulation to alleviate the symptoms of Parkinson's Disease. The problem with either approach is that the brain floats free in the skull while the probe does not, and relatively minor impacts, such as a low speed car accident, are potentially damaging. Some researchers, such as Kensall Wise at the University of Michigan, have proposed tethering 'electrodes to be mounted on the exterior surface of the brain' to the inner surface of the skull. However, even if successful, tethering would not resolve the problem in devices meant to be inserted deep into the brain, such as in the case of deep brain stimulation (DBS).

Visual prosthetics [edit]

Main article: Visual prosthetic

A visual prosthesis can create a sense of image by electrically stimulating neurons in the visual system. A camera would wirelessly transmit to an implant, the implant would map the image across an array of electrodes. The array of electrodes has to effectively stimulate 600-1000 locations, stimulating these optic neurons in the retina thus will create an image. The stimulation can also be done anywhere along the optic signal's path way. The optical nerve can be stimulated in order to create an image, or the visual cortex can be stimulated, although clinical tests have proven most successful for retinal implants.

A visual prosthesis system consists of an external (or implantable) imaging system which acquires and processes the video. Power and data will be transmitted to the implant wirelessly by the external unit. The implant uses the received power/data to convert the digital data to an analog output which will be delivered to the nerve via micro electrodes.

Photoreceptors are the specialized neurons that convert photons into electrical signals. They are part of the retina, a multilayer neural structure about 200 um thick that lines the back of the eye. The processed signal is sent to the brain through the optical nerve. If any part of this pathway is damaged blindness can occur.

Blindness can result from damage to the optical pathway (cornea, aqueous humor, crystalline lens, and vitreous). This can happen as a result of accident or disease. The two most common retinal degenerative diseases that result in blindness secondary to photoreceptor loss is age related macular degeneration (AMD) and retinitis pigmentosa (RP).

The first clinical trial of a permanently implanted retinal prosthesis was a device with a passive microphotodiode array with 3500 elements.[4] This trial was implemented at Optobionics, Inc., in 2000. In 2002, Second Sight Medical Products, Inc. (Sylmar, CA) began a trial with a prototype epiretinal implant with 16 electrodes. The subjects were six individuals with bare light perception secondary to RP. The subjects demonstrated their ability to distinguish between three common objects (plate, cup, and knife) at levels statistically above chance. An active sub retinal device developed by Retina Implant GMbH (Reutlingen, Germany) began clinical trials in 2006. An IC with 1500 microphotodiodes was implanted under the retina. The microphotodiodes serve to modulate current pulses based on the amount of light incident on the photo diode.[5]

The seminal experimental work towards the development of visual prostheses was done by cortical stimulation using a grid of large surface electrodes. In 1968 Giles Brindley implanted an 80 electrode device on the visual cortical surface of a 52-year-old blind woman. As a result of the stimulation the patient was able to see phosphenes in 40 different positions of the visual field.[6] This experiment showed that an implanted electrical stimulator device could restore some degree of vision. Recent efforts in visual cortex prosthesis have evaluated efficacy of visual cortex stimulation in a non-human primate. In this experiment after a training and mapping process the monkey is able to perform the same visual saccade task with both light and electrical stimulation.

The requirements for a high resolution retinal prosthesis should follow from the needs and desires of blind individuals who will benefit from the device. Interactions with these patients indicate that mobility without a cane, face recognition and reading are the main necessary enabling capabilities.[7]

The results and implications of fully functional visual prostheses are exciting. However, the challenges are grave. In order for a good quality image to be mapped in the retina a high number of micro-scale electrode arrays are needed. Also, the image quality is dependent on how much information can be sent over the wireless link. Also this high amount of information must be received and processed by the implant without much power dissipation which can damage the tissue. The size of the implant is also of great concern. Any implant would be preferred to be minimally invasive.[7]

With this new technology, several scientists, including Karen Moxon at Drexel, John Chapin at SUNY, and Miguel Nicolelis at Duke

University, started research on the design of a sophisticated visual prosthesis. Other scientists[who?] have disagreed with the focus of their research, arguing that the basic research and design of the densely populated microscopic wire was not sophisticated enough to proceed.

Auditory prosthetics [edit]

Main articles: cochlear implant and auditory brainstem implant

(For receiving sound)

Cochlear implants (CIs), auditory brain stem implants (ABIs), and auditory midbrain implants (AMIs) are the three main categories for auditory prostheses. CI electrode arrays are implanted in the cochlea, ABI electrode arrays stimulate the cochlear nucleus complex in the lower brain stem, and AMIs stimulates auditory neurons in the inferior colliculus. Cochlear implants have been very successful among these three categories. Today the Advanced Bionics Corporation, the Cochlear Corporation and the Med-El Corporation are the major commercial providers of cochlea implants.

In contrast to traditional hearing aids that amplify sound and send it through the external ear, cochlear implants acquire and process the sound and convert it into electrical energy for subsequent delivery to the auditory nerve. The microphone of the CI system receives sound from the external environment and sends it to processor. The processor digitizes the sound and filters it into separate frequency bands that are sent to the appropriate tonotonic region in the cochlea that approximately corresponds to those frequencies.

In 1957, French researchers A. Djourno and C. Eyries, with the help of D. Kayser, provided the first detailed description of directly stimulation the auditory nerve in a human subject.[8] The individuals described hearing chirping sounds during simulation. In 1972, the first portable cochlear implant system in an adult was implanted at the House Ear Clinic. The U.S. Food and Drug Administration (FDA) formally approved the marketing of the House-3M cochlear implant in November 1984.[9]

Improved performance in cochlea implants not only depends on understanding the physical and biophysical limitations of implant stimulation but also on an understanding of the brain's pattern processing requirements. Modern signal processing represents the most important speech information while also providing the brain the pattern recognition information that it needs. Pattern recognition in the brain is more effective than algorithmic preprocessing at identifying important features in speech. A combination of engineering, signal processing, biophysics, and cognitive neuroscience was necessary to produce the right balance of technology to maximize the performance of auditory prosthesis.[10]

Cochlear implants have been also used to allow acquiring of spoken language development in congenitally deaf children, with remarkable success in early implantations (before 2–4 years of life have been reached).[11] There have been about 80.000 children implanted worldwide.

The concept of combining simultaneous electric-acoustic stimulation (EAS) for the purposes of better hearing was first described by

C. von Ilberg and J. Kiefer, from the Universitätsklinik Frankfurt, Germany, in 1999.[12] That same year the first EAS patient was implanted. Since the early 2000s FDA has been involved in a clinical trial of device termed the "Hybrid" by Cochlear Corporation. This trial is aimed at examining the usefulness of cochlea implantation in patients with residual low-frequency hearing. The "Hybrid" utilizes a shorter electrode than the standard cochlea implant, since the electrode is shorter it stimulates the basil region of the cochlea and hence the high-frequency tonotopic region. In theory these devices would benefit patients with significant low-frequency residual hearing who have lost perception in the speech frequency range and hence have decreased discrimination scores.[13]

For producing sound see Speech synthesis.

Prosthetics for pain relief [edit]

Main article: Spinal Cord Stimulator

The SCS (Spinal Cord Stimulator) device has two main components: an electrode and a generator. The technical goal of SCS for neuropathic pain is to mask the area of a patient's pain with a stimulation induced tingling, known as "paresthesia", because this overlap is necessary (but not sufficient) to achieve pain relief.[14] Paresthesia coverage depends upon which afferent nerves are stimulated. The most easily recruited by a dorsal midline electrode, close to the pial surface of spinal cord, are the large dorsal column afferents, which produce broad paresthesia covering segments caudally.

In ancient times the electrogenic fish was used as a shocker to subside pain. Healers had developed specific and detailed techniques to exploit the generative qualities of the fish to treat various types of pain, including headache. Because of the awkwardness of using a living shock generator, a fair level of skill was required to deliver the therapy to the target for the proper amount of time. (Including keeping the fish alive as long as possible) Electro analgesia was the first deliberate application of electricity. By the nineteenth century, most western physicians were offering their patients electrotherapy delivered by portable generator.[15] In the mid-1960s, however, three things converged to ensure the future of electro stimulation.

1. Pacemaker technology, which had it start in 1950, became available.
2. Melzack and Wall published their gate control theory of pain, which proposed that the transmission of pain could be blocked by stimulation of large afferent fibers.[16]
3. Pioneering physicians became interested in stimulating the nervous system to relieve patients from pain.

The design options for electrodes include their size, shape, arrangement, number, and assignment of contacts and how the electrode is implanted. The design option for the pulse generator include the power source, target anatomic placement location, current or voltage source, pulse rate, pulse width, and number of independent channels. Programming options are very numerous (a four-contact electrode offers 50 functional bipolar combinations). The current devices use computerized equipment to find the best options for use. This reprogramming option compensates for postural changes, electrode migration, changes in pain location, and suboptimal electrode placement.[17]

Motor prosthetics [edit]

Devices which support the function of autonomous nervous system include the implant for bladder control. In the somatic nervous system attempts to aid conscious control of movement include Functional electrical stimulation and the lumbar anterior root stimulator.

Bladder control implants [edit]

Main article: Sacral anterior root stimulator

Where a spinal cord lesion leads to paraplegia, patients have difficulty emptying their bladders and this can cause infection. From 1969 onwards Brindley developed the sacral anterior root stimulator, with successful human trials from the early 1980s onwards.[18] This device is implanted over the sacral anterior root ganglia of the spinal cord; controlled by an external transmitter, it delivers intermittent stimulation which improves bladder emptying. It also assists in defecation and enables male patients to have a sustained full erection.

The related procedure of sacral nerve stimulation is for the control of incontinence in able-bodied patients.[19]

Motor prosthetics for conscious control of movement [edit]

Main article: Brain-computer interface

Researchers are currently investigating and building motor neuroprosthetics that will help restore movement and the ability to communicate with the outside world to persons with motor disabilities such as tetraplegia or amyotrophic lateral sclerosis. Research has found that the stratium plays a crucial role in motor sensory learning. This was demonstrated by an experiment in which lab rats' firing rates of the stratium was recorded at higher rates after performing a task consecutively.

To capture electrical signals from the brain, scientists have developed microelectrode arrays smaller than a square centimeter that can be implanted in the skull to record electrical activity, transducing recorded information through a thin cable. After decades of research in monkeys, neuroscientists have been able to decode neuronal signals into movements. Completing the translation, researchers have built interfaces that allow patients to move computer cursors, and they are beginning to build robotic limbs and exoskeletons that patients can control by thinking about movement.

The technology behind motor neuroprostheses is still in its infancy. Investigators and study participants continue to experiment with different ways of using the prostheses. Having a patient think about clenching a fist, for example, produces a different result than having him or her think about tapping a finger. The filters used in the prostheses are also being fine-tuned, and in the future, doctors hope to create an implant capable of transmitting signals from inside the skull wirelessly, as opposed to through a cable.

Preliminary clinical trials suggest that the devices are safe and that they have the potential to be effective.[citation needed] Some patients have worn the devices for over two years with few, if any, ill effects.[citation needed]

Prior to these advancements, Philip Kennedy (Emory and Georgia Tech) had an operable if somewhat primitive system which allowed an individual with paralysis to spell words by modulating their brain activity. Kennedy's device used two neurotrophic electrodes: the first was implanted in an intact motor cortical region (e.g. finger representation area) and was used to move a cursor among a group of letters. The second was implanted in a different motor region and was used to indicate the selection.[20]

Developments continue in replacing lost arms with cybernetic replacements by using nerves normally connected to the pectoralis muscles. These arms allow a slightly limited range of motion, and reportedly are slated to feature sensors for detecting pressure and temperature.[21]

Dr. Todd Kuiken at Northwestern University and Rehabilitation Institute of Chicago has developed a method called targeted reinnervation for an amputee to control motorized prosthetic devices and to regain sensory feedback.

Sensory/motor prosthetics [edit]

In 2002 an array of 100 electrodes was implanted directly into the median nerve fibers of scientist Kevin Warwick. The recorded signals were used to control a robot arm developed by Warwick's colleague, Peter Kyberd and was able to mimic the actions of Warwick's own arm.[22] Additionally, a form of sensory feedback was provided via the implant by passing small electrical currents into the nerve. This caused a contraction of the first lumbrical muscle of the hand and it was this movement that was perceived.[22]

Cognitive prostheses [edit]

Cognitive prostheses seek to restore cognitive function to individuals with brain tissue loss due to injury, disease, or stroke by performing the function of the damaged tissue with integrated circuits.[23] The theory of localization states that brain functions are localized to a specific portion of the brain.[24] However, recent studies on brain plasticity suggest that the brain is capable of rewiring itself so that an area of the brain traditionally associated with a particular function (e.g. auditory cortex) can perform functions associated with another portion of the brain. (e.g. auditory cortex processing visual information).[25] Implants could take advantage of brain plasticity to restore cognitive function even if the native tissue has been destroyed.

Applications [edit]

Alzheimer's disease [edit]

Alzheimer's disease is a presenile dementia characterized cellularly by the appearance of unusual helical protein filaments in nerve cells (neurofibrillary tangles), and by degeneration in cortical regions of brain, especially frontal and temporal lobes.[26] It is projected to affect more than 107 million people worldwide by the year 2050.[27] Due to increased life spans, more and more people are being affected by Alzheimer's disease. Alzheimer's disease renders individuals incapable of supporting themselves. Many of the more severe cases of Alzheimer's patients end up in nursing homes. Even a small measure of success by cognitive implants would help keep Alzheimer's patients out of nursing homes.

Hippocampal deficits [edit]

Dr. Theodore Berger at the University of Southern California, and Drs. Sam A. Deadwyler and Robert E. Hampson at Wake Forest Baptist Medical Center, are developing a prosthetic for treatments of hippocampal detriments including Alzheimer's.[23] Degenerative hippocampal neurons are the root cause of the memory disorders that accompany Alzheimer's disease. Also, hippocampal pyramidal cells are extremely sensitive to even brief periods of anoxia, like those that occur during stroke. The classic case of H.M. Henry Molaison established the role of the hippocampus in the formation of new memories. Loss of hippocampal neurons in the dentate gyrus, an area associated with this new memory formation has been attributed to blunt head trauma.[28] Hippocampal dysfunction has also been linked to epileptic activity.[23] This demonstrates the wide scope of neural damage and neurodegenerative disease conditions for which a hippocampal prosthesis would be clinically relevant.

Traumatic brain injury [edit]

More than 1.7 million people in the United States suffer traumatic brain injury (TBI) every year.[29] Orthosis for TBI patients to control limb movement via devices that read neurons in brain, calculate limb trajectory, and stimulate needed motor pools to make movement. [30]

Parkinson's disease [edit]

Nearly 1 million people in the United States are affected by Parkinson's disease.[31] Deep brain stimulation relieves symptoms of Parkinson's disease for numerous patients.[32] Parkinson's Disease patients could benefit from a cortical device that mimics the natural signals needed to promote dopamine production. Another possible avenue for mitigation of PD is a device that supplements dopamine when given specific neuronal inputs which would let the body regulate dopamine levels with its intrinsic sensors.

Speech deficits [edit]

Approximately 7.5 million people in the United States have trouble speaking.[33] Many of these can be attributed to aphasias. The success of cochlear implants suggest that cortical implants to the speech areas of the brain can be developed to improve speech in such patients.

Paralysis [edit]

According to the Christopher and Dana Reeve Foundation's[34] Paralysis Resource Center, approximately 6 million people are living with paralysis in the United States. Paralysis results from many sources, stroke, traumatic brain injury, neurodegenerative diseases like multiple sclerosis and Lou Gehrig's disease, and congenital sources. Many patients would benefit from a prosthetic device that controls limb movement via devices that read neurons in brain, calculate limb trajectory, and stimulate the needed motor pools to make movement. This technology is being developed at the Andersen Lab, located at the California Institute of Technology. The goal is to develop a device to enable locked in patients, those without the ability to move or speak, to communicate with others.

Spinal cord injuries [edit]

Neuroprosthetics have been shown to be an effective and safe method in restoring hand movement in adults following spinal cord injuries. This neuroprosthesis consists of an implanted receiver-stimulator, an external shoulder position sensor and a terminal electrode. The terminal electrode is placed on the motor point of a muscle, this enables a low electrical threshold to be utilized . The external sensor measures voluntary movements that occur in the contralateral (opposite) shoulder and bases motor output commands on this information. A radiofrequency signal is then transmitted to the implanted receiver stimulator and is later converted to an electrical stimuli that depolarizes the peripheral nerve. Evaluations of the neuroprosthetic are performed based on clinical outcome which measure the improvement of hand function on scales of impairment and performance of daily living.[35]

Obstacles [edit]

Mathematical modeling [edit]

Accurate characterization of the nonlinear input/output (I/O) parameters of the normally functioning tissue to be replaced is paramount to designing a prosthetic that mimics normal biologic synaptic signals.[36][37] Mathematical modeling of these signals is a complex task "because of the nonlinear dynamics inherent in the cellular/molecular mechanisms comprising neurons and their synaptic connections."[38][39][40] The output of nearly all brain neurons are dependent on which post-synaptic inputs are active and in what order the inputs are received. (spatial and temporal properties, respectively).[23]

Once the I/O parameters are modeled mathematically, integrated circuits are designed to mimic the normal biologic signals. For the prosthetic to perform like normal tissue, it must process the input signals, a process known as transformation, in the same way as normal tissue.

Size [edit]

Implantable devices must be very small to be implanted directly in the brain, roughly the size of a quarter. One of the example of microimplantable electrode array is the Utah array.[41]

Wireless controlling devices can be mounted outside of the skull and should be smaller than a pager.

Power consumption [edit]

Power consumption drives battery size. Optimization of the implanted circuits reduces power needs. Implanted devices currently need on-board power sources. Once the battery runs out, surgery is needed to replace the unit. Longer battery life correlates to fewer surgeries needed to replace batteries. One option that could be used to recharge implant batteries without surgery or wires is being used in powered toothbrushes.[citation needed] These devices make use of inductive coupling to recharge batteries. Another strategy is to convert electromagnetic energy into electrical energy, as in radio-frequency identification tags.

Biocompatibility [edit]

Cognitive prostheses are implanted directly in the brain, so biocompatibility is a very important obstacle to overcome. Materials used in the housing of the device, the electrode material (such as iridium oxide[42]), and electrode insulation must be chosen for long term implantation. Subject to Standards: ISO 14708-3 2008-11-15, Implants for Surgery - Active implantable medical devices Part 3: Implantable neurostimulators.

Crossing the blood–brain barrier can introduce pathogens or other materials that may cause an immune response. The brain has its own immune system that acts differently from the immune system of the rest of the body.

Questions to answer: How does this affect material choice? Does the brain have unique phages that act differently and may affect materials thought to be biocompatible in other areas of the body?

Data transmission [edit]

Wireless Transmission is being developed to allow continuous recording of neuronal signals of individuals in their daily life. This allows physicians and clinicians to capture more data, ensuring that short term events like epileptic seizures can be recorded, allowing better treatment and characterization of neural disease.

A small, light weight device has been developed that allows constant recording of primate brain neurons at Stanford University.[43] This technology also enables neuroscientists to study the brain outside of the controlled environment of a lab.

Methods of data transmission must be robust and secure. Neurosecurity is a new issue. Makers of cognitive implants must prevent unwanted downloading of information or thoughts[citation needed] from and uploading of detrimental data to the device that may interrupt function.

Correct implantation [edit]

Implantation of the device presents many problems. First, the correct presynaptic inputs must be wired to the correct postsynaptic inputs on the device. Secondly, the outputs from the device must be targeted correctly on the desired tissue. Thirdly, the brain must learn how to use the implant. Various studies in brain plasticity (int link) suggest that this may be possible through exercises designed with proper motivation.

Current developments [edit]

Andersen Lab [edit]

The Andersen Lab[44] builds on research done previously by Musallam and show that high-level cognitive signals in the post parietal cortex, or PPC, can be used to decode the target position of reaching motions.[45] Signals like these could be used to directly control a prosthetic device. Functionally speaking, the PPC is situated between sensory and motor areas in the brain. It is involved in converting sensory inputs into plans for action, a phenomenon known as sensory – motor integration.

Within the PPC is an area known as the post parietal reach region, or PRR for short. This area has been shown to be most active when an individual is planning and executing a movement. The PRR receives direct visual information, indicating that vision may be the primary sensory input. The PRR encodes the targets for reaching in visual coordinates relative to the current direction of gaze AKA retinal coordinates.[46] Because it is coding the goal of the movement and not all the different variables required for the limb to contact the target, the planning signals of the PRR are considered cognitive in nature. Decoding these signals is important to help paralyzed patients, especially those with damage to areas of the brain that calculate limb movement variables, or relay this information to motor neurons. Perhaps the most astonishing possibility is utilizing these signals to provide 'locked in' individuals, those without the ability to move or speak, an avenue of communication.

First, Andersen and colleagues placed electrode arrays onto the dorsal premotor cortex, the PRR, and medial interparietal area (MIP) of monkeys to record signals made by these regions while the monkeys looked at a computer screen. After the monkeys touched a central cue spot on the screen and looked at a central fixation point (red), another cue (green) popped up briefly then disappeared. The monkeys were given a juice reward if they reached to where the newly vanished target was at the end of a short memory period, about 1.5 seconds. The recordings were made when the monkeys were planning movement, but sitting motionless in the dark absent of eye movements, ensuring that motor and sensory information were not influencing the planning activity.

Next, the researchers conducted brain-control trials using neural activity data recorded from 2 tenths of a second to 1 second of the memory period to decode the intended reach destination. A brain-machine interface used the decoded data to move a cursor to the spot on the screen where the monkeys planned to move, without using their limbs. Monkeys were rewarded with juice if the correct target was decoded and the cue was flashed again, providing visual reinforcement. After a month or two of training, the monkeys were much better at hitting the target. This learning is a testament to the brain's natural plasticity, and creates an opportunity for patients to improve how they operate the prosthesis with training. Each time the patient uses the prosthetic system, the brain could automatically make subtle adjustments to the input signal recorded by the system.

Finally, the researchers used reach trials to decode intentions in healthy monkeys. However, paralyzed patients cannot perform reach trials for the scientists to record reach intention data. Adaptive databases overcome this scenario. Each time a reach decoding is successful, it is added to the database. If the number of database entries is kept constant, one trial, (a less successful one) must be deleted. Eventually the database will contain only successful decodes, making the system work better each time the patient uses it. This suggests a FIFO, or first-in, first-out, setup. The oldest data drops out first. Initially filling the database will be difficult, but with rigorous training and many trials, the system will be able to accurately discern the user's intentions. This process, along with the brain's plasticity, should enable people to control a myriad of prostheses, and perhaps even motorized wheel chairs.

Furthermore, in the future precision devices such as surgical tools could be controlled directly by the brain instead of controls manipulated by the motor system.

Hippocampal prosthetic [edit]

Main article: Hippocampal prosthesis

Dr. Theodore Berger's research lab at the University of Southern California seeks to develop models of mammalian neural systems, currently the hippocampus, essential for learning and memory. The goal is to make an implantable device that replicates the way living hippocampal neurons behave and exchange electrical signals. If successful, it would be a large step towards a biomedical solution for Alzheimer's symptoms. Complications from brain injury to motor areas of the brain like reduced coordination could be improved. Speech and language problems caused by stroke could be reversed. To accomplish this, the device will listen for neuronal signals going to the hippocampus with implanted electrode arrays, calculate what the outgoing response of normal hippocampus neurons would be, and then to stimulate neurons in other parts of the brain, hopefully just like the tissue did before damage or degeneration. Prototypes concepts for the device are currently being tested in the laboratories of Dr. Sam A. Deadwyler and Robert E. Hampson at Wake Forest Baptist Medical Center.[47]

Technologies involved [edit]

Local field potentials [edit]

Local field potentials (LFPs) are electrophysiological signals that are related to the sum of all dendritic synaptic activity within a volume of tissue. Recent studies suggest goals and expected value are high-level cognitive functions that can be used for neural cognitive prostheses.[48] Also, Rice University scientists have discovered a new method to tune the light-induced vibrations of nanoparticles through slight alterations to the surface to which the particles are attached. According to the University, the discovery could lead to new applications of photonics from molecular sensing to wireless communications. They used ultrafast laser pulses to induce the atoms in gold nanodisks to vibrate.[49]

Automated movable electrical probes [edit]

One hurdle to overcome is the long term implantation of electrodes. If the electrodes are moved by physical shock or the brain moves in relation to electrode position, the electrodes could be recording different nerves. Adjustment to electrodes is necessary to maintain an optimal signal. Individually adjusting multi electrode arrays is a very tedious and time consuming process. Development of automatically adjusting electrodes would mitigate this problem. Anderson's group is currently collaborating with Yu-Chong Tai's lab and the Burdick lab (all at Cal Tech) to make such a system that uses electrolysis-based actuators to independently adjust electrodes in a chronically implanted array of electrodes.[50]

MRI [edit]

Used for imaging to determine correct positionings.

Imaged guided surgical techniques [edit]

Image-guided surgery is used to precisely position brain implants.[48]

Future directions [edit]

Self-charging implants that use bioenergy to recharge would eliminate the need for costly and risky surgeries to change implant batteries.

Memory/Brain off-loading and subsequent uploading to learn new information quickly. Researchers at the Georgia Institute of Technology are researching mammalian memory cells to determine exactly how we learn. The techniques used in the Potter Lab can be used to study and enhance the activities of neural prosthetics devices.

Controlling complex machinery with thoughts instead of converting motor movements into commands for machines would allow greater accuracy and enable users to distance themselves from hazardous environments.

Other future directions include devices to maintain focus, to stabilize/induce mood, to help patients with damaged cortices feel and express emotions, and to enable true telepathic communication, not simply picking up visual/auditory cues and guessing emotional state or subject of thought from context.

Commercial technology [edit]

Medtronic and Advanced Bionics are significant commercial names in the emergent market of Deep Brain Stimulation. Cyberkinetics is the first venture capital funded neural prosthetic company.

See also [edit]

- Biomedical engineering
- Brain-reading
- Cyborg
- Neural engineering
- Neurosecurity
- Prosthetics
- Simulated reality
- Prosthetic Neuronal Memory Silicon Chips

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External links [edit]

- The open-source Electroencephalography project and Programmable chip version, *Sourceforge* open source EEG projects
- Dr. Theodore W. Berger's website
- Neuroprosthetics Research Society (NRS) - Neuroprosthetic.org
- CIMIT - Center For Integration Of Medicine And Innovative Technology - Advances & Research in Neuroprosthetics