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What is brain-computer interface (BCI)?

BCI is a direct connection between brain activity and a computer or any external device. An individual's brain activity controls various tasks directly - without any motor involvement using an external device. Brain-machine interfaces (BMIs) can provide feedback from ongoing brain activity (e.g. a moving cursor on a computer screen is powered by brain waves). Brain activity is also used to move a neuroprosthetic device, a robot, or to stimulate the brains of other organisms. Usually electroencephalography (EEG), near-infrared spectroscopy (NIRS), or invasive recordings from brain cells are used when employing BCIs. Recently, we developed a BCI based on functional magnetic resonance imaging (fMRI). People can easily learn to control their brain activity voluntarily through feedback and reward; this process is called neurofeedback.

What effect has your research had on treating brain injuries, as well as psychiatric and neurological disorders?

Our research has improved quality of life for individuals suffering from severe chronic strokes and has enabled communication for completely paralyzed and locked–in patients. Neurofeedback has improved intractable epilepsy and attention deficit disorder, and may have positive effects on symptoms of obsessive compulsive disorders, schizophrenia, and psychopathy. For the latter psychiatric diseases, the effects have so far only been demonstrated in the laboratory with fMRI neurofeedback. It is not clear whether the achieved behavioral changes will generalize to real life in psychiatric patients. However, these BCI-neurofeedback-techniques will become an alternative to invasive deep brain stimulation (DBS) because they impose no risk and patients only need to train for longer periods of time. Chronic stroke patients or paralyzed patients with spinal cord lesions can move a neuroprosthetic device or an orthosis fixed to their limb by just thinking and intending the movement; the brain activity underlying the intended movement is directly translated into the movement of the neuroprosthetic device, allowing the patient voluntary control of the paralyzed limb.

How can brain-computer interface help prevent and/or treat diseases such as epilepsy, Alzheimer's, and Parkinson's?

Effects on Alzheimer's were never tested; Parkinson's is being investigated right now. Intractable epilepsy was treated successfully in our clinic with neurofeedback of slow cortical brain potentials (fluctuations of voltage between parts of the cerebral cortex) as measured by the EEG. At the Maudsley Institute in London, intractable epilepsy was treated successfully with neurofeedback of skin conductance, which also affects slow cortical potentials. The patients watch over many sessions of a cursor moving on a screen from left to right. The cursor represents their brain activity, in this case, their slow cortical potentials. Slow cortical potentials indicate the state of excitation of the neuronal tissue. Epileptic seizures are caused by overexcitement of the brain with large slow cortical potentials; patients learn to reduce this overexcitement before a seizure starts by reducing the power of their slow cortical potentials by watching the cursor on the screen. Whenever they move the cursor voluntarily to the correct target on the screen (reducing their brain excitation), they are rewarded by the computer and the therapist.

What are the ethical decisions that patients, caregivers, and medical personnel face when using brain-based communication devices?

They face the same therapeutic decisions that other patients, caregivers, and medical personnel face toward severe and often fatal diseases. Patients with complete paralysis learn to communicate with BMIs, which reactivate their will to live and to participate in social life. Many patients with diseases such as amyotrophic lateral sclerosis had previously decided to die before accepting artificial respiration because they feared their complete dependency on others and anticipated their locked-in state with horror. Now, they may decide to live with a BMI that facilitates communication. Researchers found that quality of life was very high for such completely paralyzed patients if they were able to communicate.

If BMIs are sold to the general population, however, I see an ethical societal problem. Uncontrolled use of brain wave control may have serious negative consequences on concentration and attention (such as driving in traffic and reducing brain excitation) or the military could misuse this technology to train its soldiers' brains to become more aggressive.

In your opinion, which aspects of BCI technology will have the greatest impact on the healthcare field, and why?

BCI technology will have the greatest impact on stroke patients because it is more efficient than other rehabilitation methods toward severe stroke and no other alternatives are currently available. If the experiments on psychiatric patients are successful in real life, the impact may be substantial because psychopharmacological drugs are either inefficient or have unwanted, severe side effects; similarly, deep brain stimulation is risky, expensive, and only applicable in some extreme cases.

Spinal cord patients with severe paralysis and patients with cerebral palsy and other debilitating diseases of the spinal cord and the brain will also profit from brain-derived neuroprostheses.

If you take quality of life as a measure, then BCIs for completely paralyzed patients are life savers because they allow patients to participate in social and emotional life again. However, it is difficult to predict what will happen if cheap and easy-to-use BCIs for everyone become available. Many types of positive and negative social scenarios are possible.