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Moving Thoughts

Two subjects during a computer game (tennis) controlled via a BCI

Tetraplegic patient with a BCI controlled orthosis and functional electrical stimulation grasp restoration, respectively

The brain consists of approximately 10 billion nerve cells that are interlinked in a dense network. Every thought leads to changes in the activities of dispersed neuron populations and to corresponding fluctuations in spontaneous bioelectrical brain activity, the electroencephalogram (EEG). With the help of electrodes applied to the intact scalp, the EEG can be registered, scanned and processed by computer in real time. With applicable mathematical methods, the thought-specific information can be gleaned from the EEG and converted into control signals.

This type of system that analyzes EEG signals from the brain in real time and converts them into control signals is referred to as a brain-computer interface (BCI). A mental strategy that can be used for BCI applications is the process of thinking about certain forms of movement (motor imagery) such as imagining moving one's hand, foot or tongue. This visualization process activates neuron populations in the brain that are similar to those that are needed to carry out the particular motion. Every successful BCI application requires a learning or training phase that can extend over several weeks (often months in the case of patients). In this training phase, the trainee must imagine certain patterns of motion, and the computer learns to recognize the corresponding EEG pattern. Following completion of the training phase, a personalized classifier is placed at the disposal of the trainee, who can then begin to work with the BCI application online and in real time.

Current BCI applications enable hand-free writing with thoughts (Virtual Keyboard) by patients with Locked-in Syndrome, and control of neuro-prostheses by patients with a severe transverse lesion of the spinal cord. The Virtual Keyboard, a device developed at the Technical University of Graz (TU Graz), is a mental communication system that is based on real-time evaluation of the oscillating fluctuations of brain potential. Patients who have learned to produce certain detectable EEG patterns—for example, motor imagery—can use this capability to select letters or words from a computer menu directly with their brain activity. The system is based upon successive dichotomous selection steps: beginning with the entire alphabet, a series of binary decisions makes it possible to halve the number of available letters in step-by-step fashion and to finally arrive at the desired letter. The writing speed that can currently be achieved is one to four letters per minute.

Another BCI application is the mental control of computer games that involve navigation

in virtual space. The very act of thinking about moving the left or right hand can shift an object's position in a virtual environment either to the left or to the right. In order to generate such conditions of virtual reality, scientists at the TU Graz utilize a head-mounted display (HMD) featuring a special set of goggles that positions two small TFT screens directly in front of the eyes and controls them with two separate signals. Another scenario is that of walking down a virtual street. From the process of imagining leg movements, the EEG-based BCI extracts a control signal that makes it possible to navigate in a virtual environment. (This research work at the TU Graz's BCI Laboratory is being performed within the framework of the EU's PRESENCIA project and an FWF project under the direction of Univ.-Prof. Dr. G. Pfurtscheller).
In addition to carrying out concrete control tasks that need to be run as quickly and error-free as possible, a BCI can also be used for direct online transformation of brain activity into acoustic or graphic patterns. This is a matter of converting high-dimensional EEG parameters into dynamic, alterable three-dimensional objects like moving faces or sound patterns. One potential application of this sort of 3-D feedback is in biofeedback therapy in conjunction with the rehabilitation of various neurological and psychiatric conditions. For example, such feedback therapy has been proven to help in the reduction of seizures among epilepsy patients.

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Gedanken bewegen

Das Gehirn besteht aus ca. 10 Milliarden Nervenzellen, die untereinander stark vernetzt und gekoppelt sind. Jeder Gedanke führt zu Aktivitätsänderungen in verteilten Neuronenpopulationen und zu entsprechenden Änderungen in der spontanen bioelektrischen Hirnaktivität, dem Elektroencephalogramm (EEG). Das EEG kann mit Hilfe von Elektroden an der intakten Kopfhaut registriert, abgetastet und mit dem Computer in Echtzeit verarbeitet werden. Mit entsprechenden mathematischen Methoden kann die gedankenspezifische Information aus dem EEG gewonnen und in Steuersignale umgewandelt werden.
Ein solches System, das EEG-Signale vom Gehirn in Echtzeit analysiert und in Steuersignale umwandelt, wird als „Brain-Computer Interface" (BCI) bezeichnet. Als mentale Strategie für BCI-Anwendungen kann das Denken an bestimmte Bewegungsformen *(motor imagery)* verwen-