Brain-Computer Interface

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Key Points

- Brain-computer interface scope and importance.
- The demand for BCI over the world.
- History of BCI.
- Field of biocybernetics.
- Materials and methods used in BCI.
- Importance and results of BCI.

Brain-computer interfaces (BCIs) provide their users with techniques for conveying a signal and control channels that do not depend on the signals of PNS and its muscles. The current attention of the experts in BCI development comes mainly from the hope that this technology could be a valuable option for communication for those with severe motor neuron disabilities—basically the disabilities which prevent them from using voluntary motor control. Over the past five years, the flow and rate of BCI research has grown rapidly. In 1995 there were only six active BCI research groups, now there are more than 20. Experts are focusing on brain electrical activity, recorded from the scalp by electroencephalographic activity (EEG) or from within the brain as a single-unit activity, for the basis for this new control and communication aactivity.[1] During the BCI training task, an individual trainer analyses the ongoing EEG on the scalp. The classifier exploits any systematic difference between the target and non-target word ERPs, to deduce the word stimulus. The BCI gives feedback to the patient to inform them if the currently applied processing strategy generates ERP difference or not, this depends on the classifier's ability to detect a change between attended word and target word. This feedback provides patients with indirect information about the working of the patient's specific brain networks which are contributing to language solving tasks. The augmentation of these networks may be beneficial; however, they are not consciously accessible by patients or therapists, thus cannot be utilized by existing forms of language training. Also, that the BCI positively reinforces word-evoked ERPs only, whilst patients do receive feedback neither during nor after the classical tone-based oddball task. After a number of studies, it was found that, although the discriminative ERP components were similar within the diverse oddball tasks, dissociation of brain ERP topographies is well documented, for example, for tonal and phonetic tasks. Thus, we expected that our protocol might selectively train up those language skills basically sensorimotor language competence underlying our task, instead of general executive function.[2]

The demand for communication between computers and humans (brain) is greatly increasing. The brain-computer interface (BCI) is a communication technique based on the brain's neural activity and is independent of the normal output pathway of peripheral nerves and muscles from the brain; it does not involve traditional human-computer interaction like a keyboard or mouse; hence it is a novel communication channel. By collecting and analyzing electroencephalogram (EEG) signals, the BCI system gives access to a wealth of real-time brain information, which includes mental state and brain activity. There are high hopes for real-life application of the BCI system, because of real-time interaction of human and brain, accuracy, and being movement independence, including uses in medical rehabilitation, sleeping monitoring, driving, and typing. To ensure the practicality of EEG, a suitable electrode needs to have many important properties, like installation and cleaning shall be done with ease, having high conductivity, long-term effectiveness, and biocompatibility, and being comfortable to wear. In many BCI studies, commercial dry electrodes and wet electrodes have been widely used to collect EEG signals.[3]

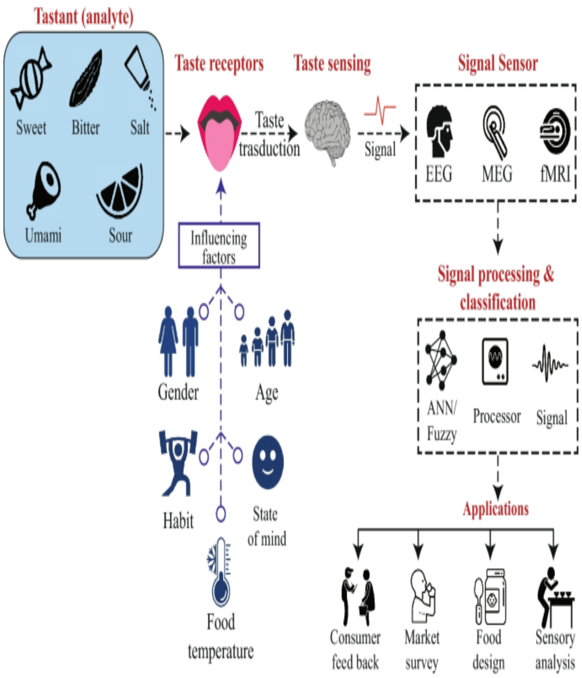

Figure 1*: BCI technology*[3]

History of BCI:

There was speculation that devices could be controlled by using brain signals, hence following the work of Hans Berger in 1929 on a device known as an electroencephalogram (EEG), it was able to record electrical potentials generated by brain activity. This remained speculation for a very long time. As reviewed by Wolpaw and colleagues, 40 years later, in the 1970s, primitive control systems were developed by researchers based on electrical activity recorded from the head. The Pentagon's Advanced Research Projects Agency (DARPA), the same agency which was involved in developing the first versions of the Internet, funded research focused on developing bionic devices that would aid soldiers. However, early research which was conducted by George Lawrence and his coworkers focused on developing techniques to improve the performance of soldiers in tasks that had high mental loads. This produced a lot of insight on methods of autoregulation and cognitive biofeedback; thus, no usable devices were produced. DARPA expanded its focus toward a more general field of biocybernetics. The main aim was to explore the possibility of controlling devices through the computerized processing of any biological signal.

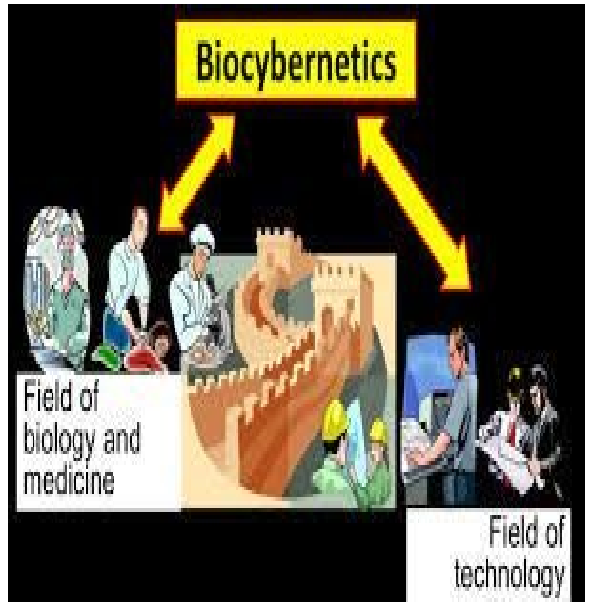

Figure 2*: Biocybernetics and field of biology and technology*[4]

Jacques Vidal from UCLA's BCI Laboratory provided proof that single-trial visual-evoked potentials could be used as a conveying channel that is effective enough to control a cursor through a two-dimensional maze (Vidal, 1977). Hence it was proved by Vidal's work and other groups that signals from brain activity could be used to effectively communicate a user's intent. It also created a vivid separation between those systems utilizing EEG activity and those that used EMG (electromyogram) activity generated from the scalp or facial muscular movements. BCI system's future work expanded to use neural activity signals recorded by EEG as well as by other imaging techniques. Present BCI-based tools can help users in communication, daily life activities, environmental control, exercise, and movement, with very limited potential and mostly in research settings. Mild to severe muscular handicaps are noted in primary users of BCI systems. It is also developed for patients with certain mental handicaps such as Autism. Basic and applied research is being conducted with humans and animals for using BCIs in numerous clinical for handicapped and non-handicapped people[4]

Methods and materials:

Ten younger healthy adults, ten age-matched older healthy adults, and ten participants with subacute stroke underwent unimanual and bimanual BCI-FES sessions. Delta alpha ratio (DAR) and brain symmetry index (BSI) were derived from the pre-and post-resting-state EEG. However, event-related desynchronization (ERD) and laterality index were derived from movement- EEG.[5] One electroencephalography channel from the motor cortex and a frequency band was used to detect event-related desynchronization (ERD) of cortical oscillatory activity during kinesthetic wrist motor imagery (MI) and BCI calibration. The active states of ERD activity in real-time were detected by an MI-based BCI system and they produce contralateral wrist extension movements through FES of the extensor carpi radialis (ECR) muscle. FES was used to generate wrist extension at random intervals as a control condition. A total of two interventions were performed on separate days and lasted for 25 minutes. Single-pulse transcranial magnetic stimulation of the motor cortex was elicited on motor evoked potentials (MEPs) in ECR (intervention target) and flexor carpi radialis (FCR) muscles, to compare corticospinal excitability before (pre), immediately after (post0), and 30 minutes after (post30) the interventions.[6]

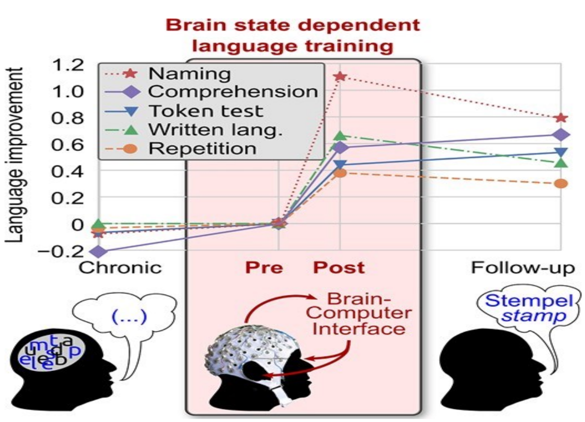

Figure 3: *Brain State-dependent Language Training*[5]

Significance:

This piece of research work indicates the efficient and proper use of the brain's ERRP response to the visual neurofeedback presented to the user, in an online hand motor imagery direction decoding experiment paradigm. The improvement of the decoding direction accuracy achieved is a promising outcome that makes the present BCI systems' usability a step closer to practical life applications.[7] The maximum accuracy achieved in the classification is 89.6 ± 4.6% and 61.1 ± 5.1% in binary and multiclass (seven classes) signals, respectively, for dataset 1. The efficacy of the proposed model is measured by evaluating the performance parameters such as parameters recall (REC), specificity (SPEC), precision (PREC), F1-score, and area under the curve (AUC). REC, SPEC, PREC, F1-score, and AUC are 95%, 94%, 38%, 55%, and 89% (95% CI: [0.871–0.937]), respectively were attained for binary classification. Furthermore, for multiclass classification, REC, SPEC, PREC, F1-score, and AUC are achieved as 60%, 93%, 60%, 60%, and 89% (95% CI: [0.873–0.971]), respectively.[8]

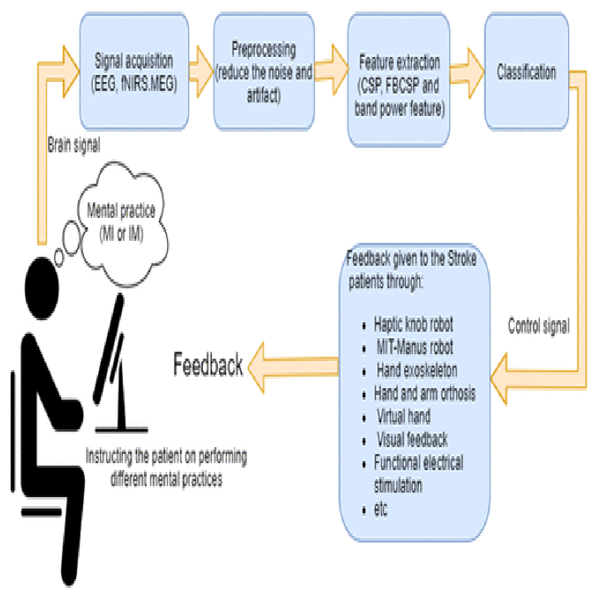

Figure 4: *Brain Signal Feedback Control System*[6]

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