Neuro-Feedback Systems: An Short Overview

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Neuro-feedback is a type of biofeedback that uses real-time displays of brain activity—most commonly electroencephalography (EEG), to teach self-regulation of brain function.

Neuro-feedback could support clinicians and therapists in the rehabilitation process of people affected by a wide range of neurological disorders and pathologies such as ADHD, epilepsy, schizophrenia and stroke.
Neuro-feedback

- Real-time feedback from brain activity
- Reinforce brain function
Typical elements

- EEG device to acquire brain signals
- Feedback presented using video or audio
Neurofeedback Applications

- Therapy
  - ADHD
  - Depressive and anxiety disorders
  - Stroke
  - Traumatic brain injury
  - Epilepsy
  - PTSD
  - ....

- Performance enhancement
Fig. 2. Data from a patient trained to self-regulate sensorimotor rhythm. He received feedback from CP4 (arrow in B) in the frequency range of 9–12 Hz. (A) Power spectrum. The voltage is plotted as a function of frequency. The solid line shows the power spectrum during relaxation and related upward cursor movement; the dashed line during imagined left-hand movement and related downward cursor movement. A voltage difference can be clearly seen in the 9–12 Hz frequency band (mu-rhythm) and also — albeit smaller — in the beta band around 18–22 Hz. (B) The topography of the determination coefficient ($r^2$), is the proportion of the total variance of the sensorimotor-rhythm amplitude that is accounted for by target position. The $r^2$ is highest (dark grey) under the feedback electrode.
Conversion of EEG Activity Into Cursor Movement

Fig. 2. Spatial filter improves signal-to-noise ratio of the signal $u_t$ of the 64 electrodes using a weight matrix $W$ as parameter. Spectral analysis is performed on a selection $q$ of the spatially filtered signals $u_t$. Thereby, $w$ selects the frequency bands. With the weights $r$ these $m$ spectrally analyzed signals $b_t$ are linearly combined. The resulting scalar $c_{\tau}$ is normalized ($x_{\tau}$) and then mapped to a cursor position $\nu_{\tau}$ using the scalar $G$ as an input. Finally, this cursor position is represented in the context of a task (e.g., three boxes, highlighted target) on the screen ($y_{\tau}$).

Georg E. Fabiani, Dennis J. McFarland, Jonathan R. Wolpaw, and Gert Pfurtscheller, Member, IEEE
Speedy’O’Brain System

IP 192.168.0.1

IP 192.168.0.2

Mental Task
Compito Mentale
Speedy’O’Brain – Racing Mode

Mental Task

Compito Mentale

G: 1.000

Delta: 0.12 (0.65)

Delta: -0.12 (0.65)

Delta: 0.28 (0.65)

Delta: 0.20 (0.65)

Calibrated

R: 0/20
Signal Acquisition

- Scalp (EEG)
- Cortical surface
- Intracortical
- fMRI
- NIRS
- Scalp (MEG)
IEEE P2731 - Data Storage

Level 0: Brain Signals Acquisition
- Acquisition Devices
- Transducer
- Signal Acquisition and Preparation
- Preparation
  - Brain
    - EEG
    - fMRI
    - ECoG
    - PET
    - MEG
    - PN/RS
  - Others
    - EOG
    - GSR
- Data Transfer
- Offline
- Online

Level 1: BCI training
- Complementary Stages
  - (Simulated Signals, Transfer Learning, etc.)
  - Pre-processing
    - Artifact removal
    - Space and time domain filtering
    - Others
- Feature extraction
- Classifier
- Regressor
- Adjust/tune transducer
- Previous stored experience
- Online
- Offline

Level 2: Feedback
- User
  - Psychology
    - Motivation, depression, skill, stress, frustration, etc.
  - Physiology
    - P300 amplitude and latency, SSxEP freq, μ-rhythm, etc.
- Voluntary Muscles (eye gaze, arms, legs, etc.)
- Involuntary Muscles (Heart)
- Previous user experience
- Online only
- Offline only
- Online & Offline

CONTROL INTERFACE
- Encoder
  - Map of sequences of Logical symbols into Semantic Symbols
  - Logical Alphabet
  - Semantic Alphabet
  - Type a character
  - Open the door
  - Wheelchair drive
  - Phone dial
  - Select

Protocol Paradigm
- Trial Handling
- Stimuli generation
- Timing clock
- Feedback/Stimulation
- Application
  - Display
  - Communication
  - Control