HEMISFER

Hybrid Eeg-MrI and Simultaneous neuro-FEedback for brain Rehabilitation

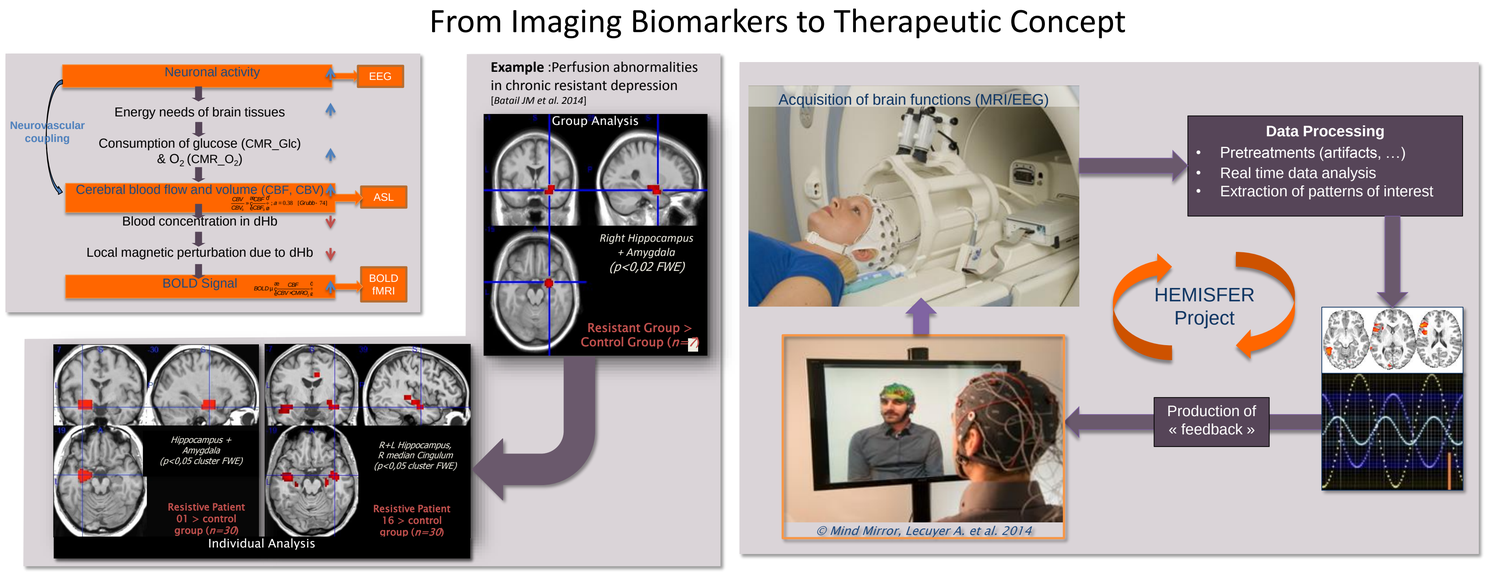
Participating Teams
Visages U746
Hybrid
Panama
EA 4712 (*associated*)
Athena (*associated*)

Start date: 01-2014

General objectives of HEMISFER

- Make full use of neurofeedback (NF) paradigm for brain self-regulation/stimulation in:
  - Rehabilitation (ADHD, Strokes, …)
  - Psychiatric disorders (anxiety, schizophrenia, resistant mood disorders, ….)
- Main Challenges:
  - Learn a coupling model associating functional and metabolic information from simultaneous Magnetic Resonance Imaging (fMRI) and Electro-encephalography (EEG)
  - Enhance the NF paradigm from the coupling model

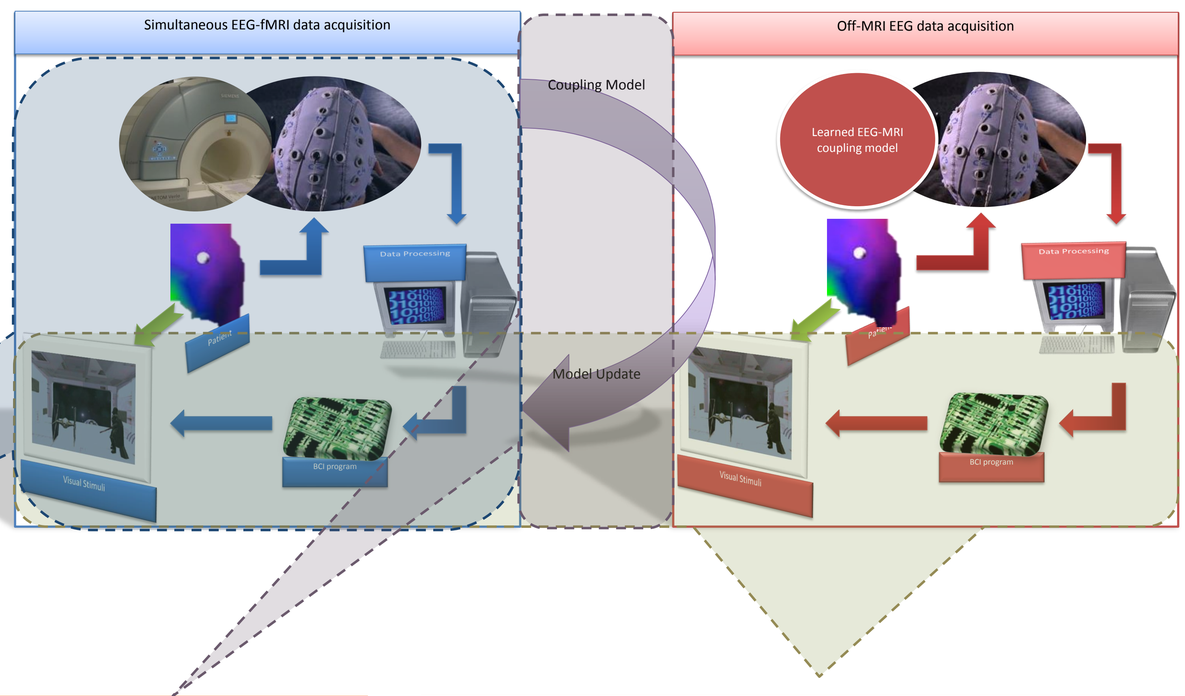
Hemisfer Context



HEMISFER Major Challenges

- Develop new NF paradigms able to profit from simultaneous EEG/fMRI/fASL recordings
  - We expect these novel paradigms to be able to concentrate the brain metabolism on specific regions of the brain
- Learn models at the signal level able to explain the coupling of EEG and fMRI signals under simple and more advanced brain stimuli (e.g. BOLD fMRI, fASL, basal ASL)
  - Learn both the domain in which brain activity is sparse (e.g., dictionary learning), and adjust parametric models of the acquisition processes
  - Achieve super-resolution in the spatial and frequency domain by expressing the problem as a linear inverse problems regularized with the learned coupled model
  - Use brain connectivity models as prior information (later stage)
- Use the learned coupling models in order to "enhance" the EEG signal while performing the same stimuli and NF tasks outside MRI

HEMISFER Paradigm



HEMISFER Integration

Current System Integration Status:

- The entire system (EEG and fMRI) is deployed and installed
- Fully synchronized
- Stimulus presentation and event registration
- Real-time EEG processing pipeline status
  - Acquisition (*data & events*)
  - Pre-processing (*filtering*)
  - Signal Processing (*band power estimation*)
  - Simple Feedback (*height changing bars*)
- Real-time fMRI Data
  - Acquisition (*data & events*)
  - Pre-processing (*realignment, etc.*)
  - Statistical Processing (*z-Score*)
  - Simple Feedback (*height changing bars*)

Future Challenges:

- Joint EEG and fMRI NF
- Development of joint modeling approaches
- Tests and evaluations with subjects
- Development of online visualization tools

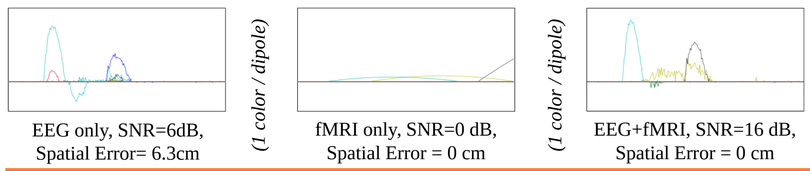
HEMISFER Coupling Model

Introduction of a new linear EEG/BOLD coupling model using sparsity-based regularization term:

$$X^* = \arg\min \left(\frac{\alpha}{2} \|E - GX\|_F^2 + \frac{1-\alpha}{2} \|F - XH\|_F^2 + \lambda\phi(X) \right)$$

EEG signal · leadfield mixing matrix · fMRI signal · Hemodynamic model · Sparse regularization

The numerical solution is found through proximal iterative algorithms



EEG only, SNR=6dB, Spatial Error= 6.3cm
fMRI only, SNR=0 dB, Spatial Error = 0 cm
EEG+fMRI, SNR=16 dB, Spatial Error = 0 cm

HEMISFER Neurofeedback

Currently working on design of a motor imagery based NF protocol compatible with EEG and fMRI

Session: # and types of runs

Rest | Pre-Training | NF Run 1 | NF Run 2 | NF Run 2 | Transfer | Rest

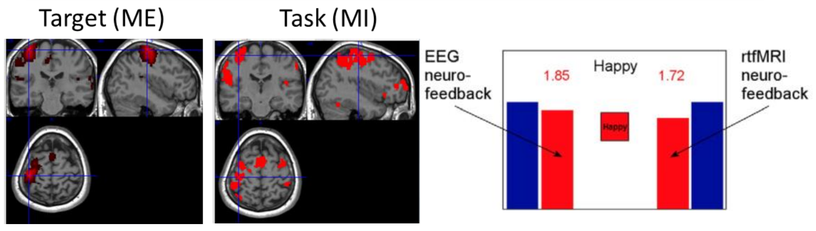
Run: experimental design (block)

R T R T R T R

Task: target, features, feedback, instructions, cues

NF target	Motor execution (ME): right-hand clenching
NF task	Motor imagery (MI)
Task length	5s – 15s ?
EEG feature	mu, beta event-related desynchronization (ERD) over sensorimotor cortex
fMRI feature	BOLD average in target regions
Feedback	Bimodal, flexible

Target (ME) Task (MI)



HEMISFER Experimental Platform

NEURINFO Research Platform

- 3T Verio by SIEMENS:
  - 70 cm Diameters– Length 173 cm
  - overweight patient, claustrophobes,
  - side positioning
  - Field of View : 50 x 50 x 45 cm
  - Gradients : 45mT/m @ 200T/m/s
  - Field homogeneity :
    - 1,2ppm (@ 40 cm)
    - 0,2ppm (@ 30 cm)
- MR-EEG BrainProducts 64 channel system
- http://www.neurinfo.org

Participating People : Elise Bannier, Christian Barillot, Jean-Marie Batail, Isabelle Bonan, Maureen Clerc, Isabelle Corouge, Dominique Drapier, Remi Gribonval, Anatole Lecuyer, Jussi Lindgren, Marsel Mano, Pierre Maurel, Thomas Oberlin, Lorraine Perronnet