Inria-Brasil Workshop on Digital Health

NERV

Systems neuroengineering to model and interface brain networks

Team leader: Fabrizio, de Vico Fallani

Inria · ICM Paris Brain Institute · Sciences Sorbonne Université · Inserm · cnrs

NERV Lab

Systems neuroengineering to model and interface brain networks

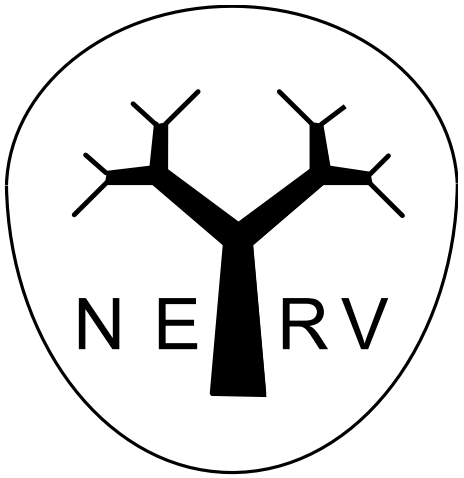
https://team.inria.fr/nerv/

ABOUT PROJECTS PEOPLE PUBLICATIONS TECHNOLOGY OUTREACH

The NERV Lab is a multidisciplinary research team supported by the French institutions Inria, Inserm, CNRS, and Sorbonne University. The team is located in the Paris Brain Institute (ICM) within the Pitie-Salpetriere hospital, one of the largest European medical centers.

The NERV Lab pursues an innovative research program at the intersection between biomedical engineering, complex systems and clinical neuroscience. Our ambition is to better understand the structural and functional organization of the human brain in health and disease.

2023



2024

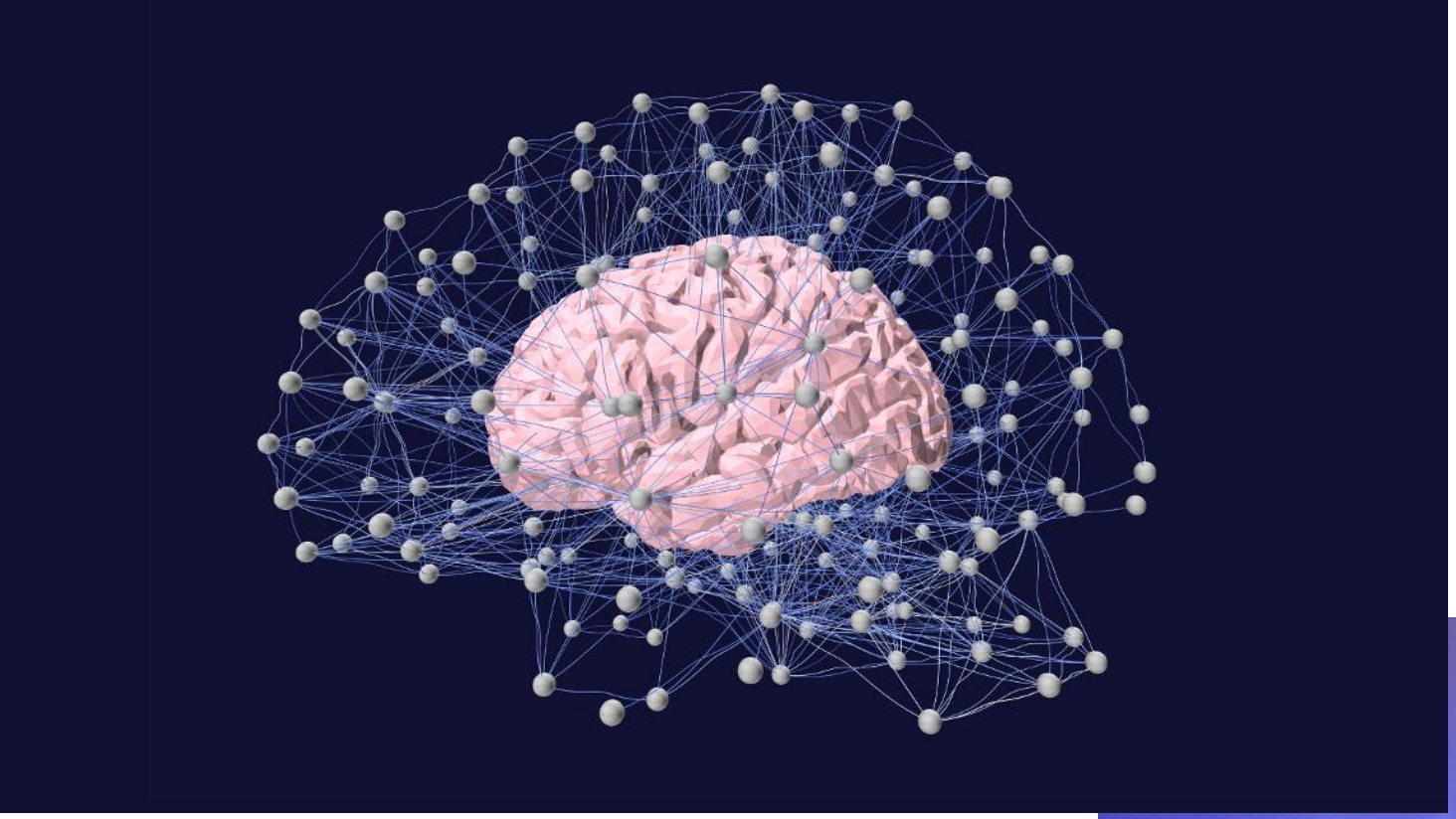
1. Fabrizio de Vico Fallani (DR2 Inria)
2. Marie-Constance Corsi (CR Inria)
3. Mario Chavez (DR2 CNRS)
4. Laurent Hugueville (IR CNRS)
5. Laurent Bougrain (Ass. Prof Univ. Lorraine)

20 Non-permanent members

- 4 Postdoc and engineers
- 9 PhD students
- (~4 MSc students/year)

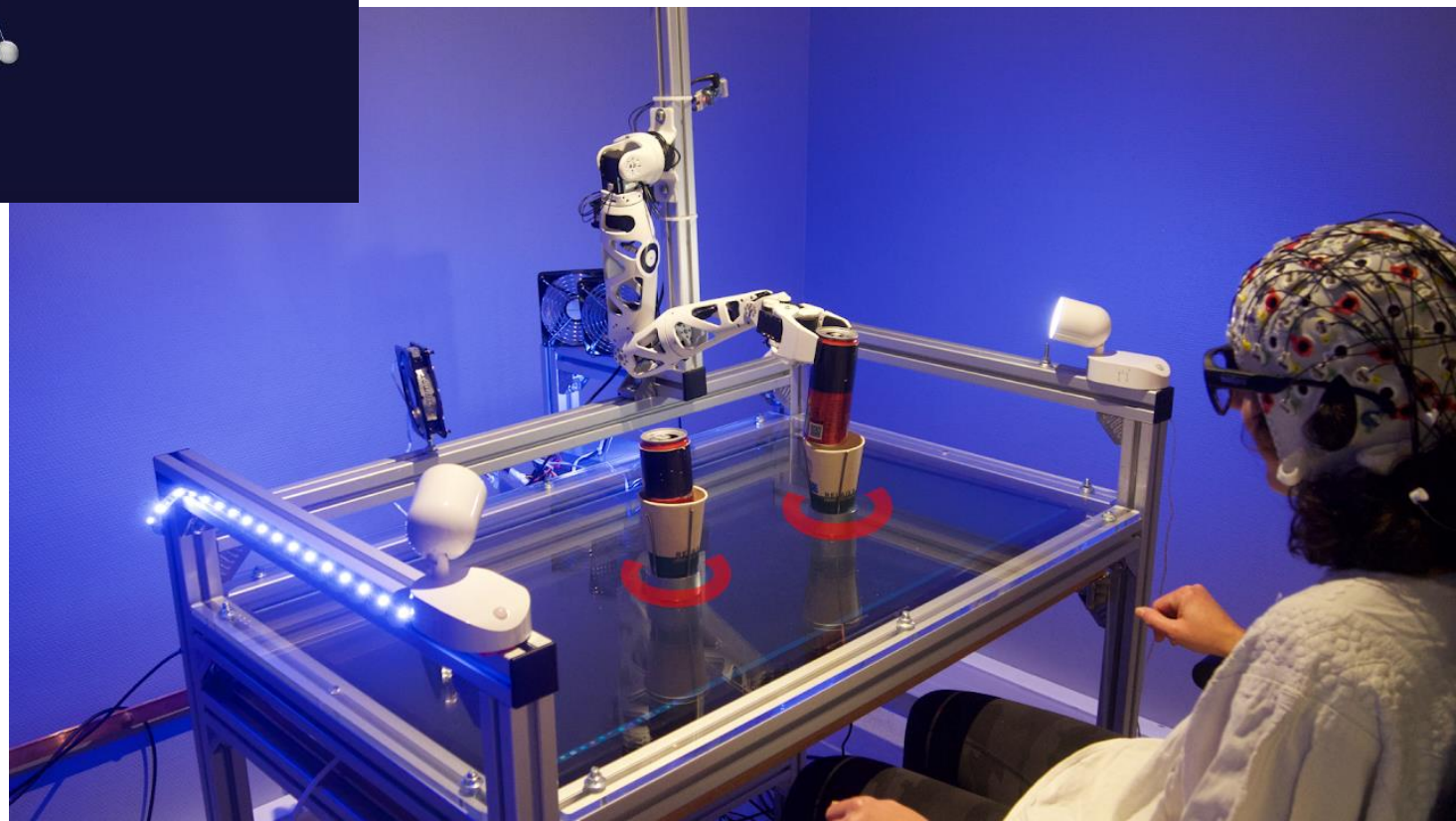
Naturally diverse

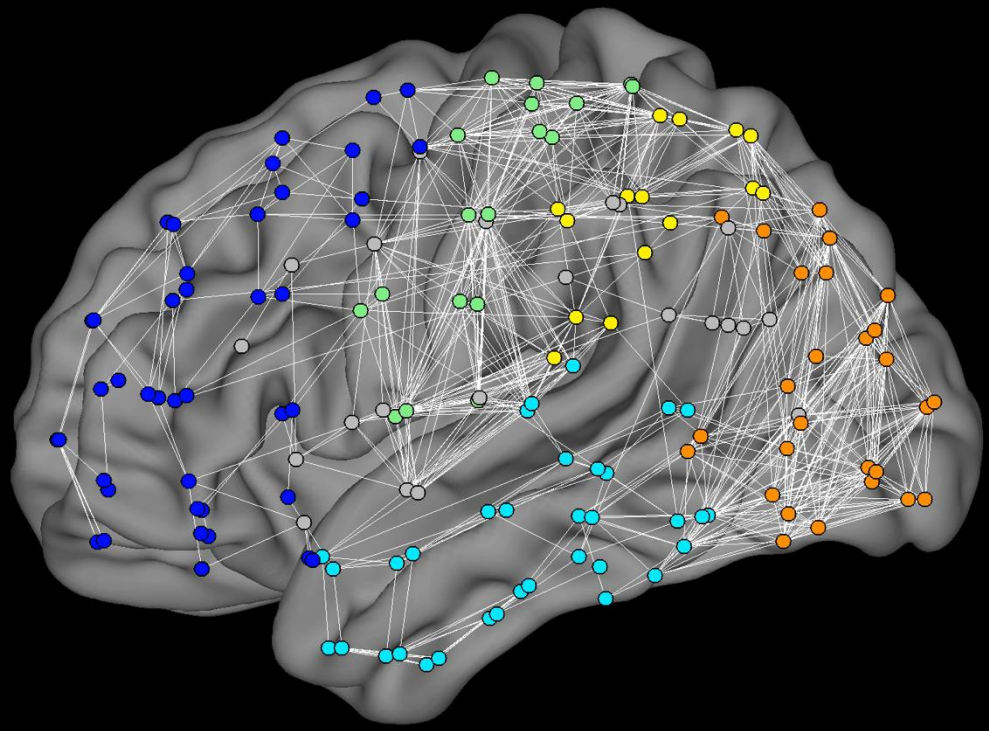
- Gender balance (~40%)
- Nationality (7 countries)
- Expertise (7 disciplines)



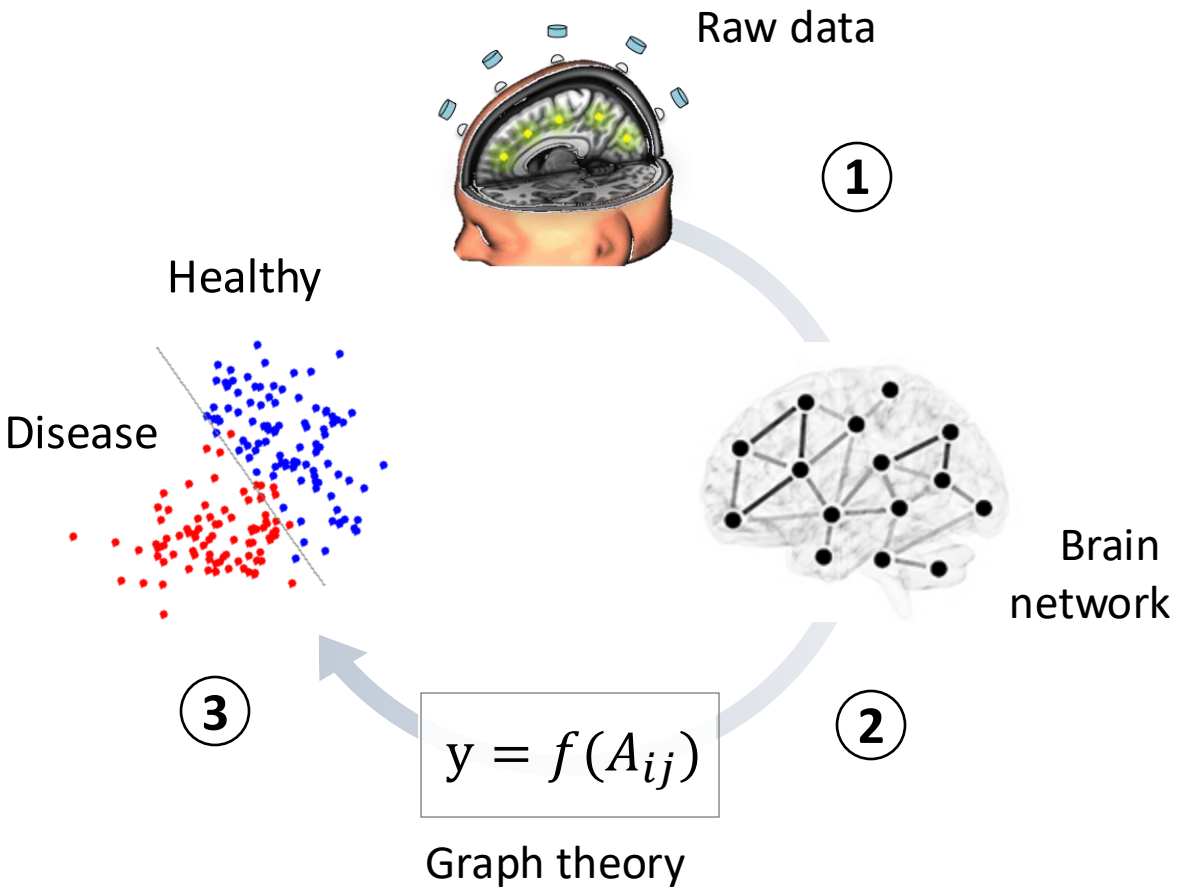
Systems neuroscience

Brain-computer interfaces





Methodological framework



De Vico Fallani et al, Phil Trans Royal Soc B, 2014

1. From raw data to connectivity

- High data complexity
  Navarro et al, IEEE TBME, 2017
- Low signal-to-noise ratio
  Chavez et al, IEEE TNSRE, 2018

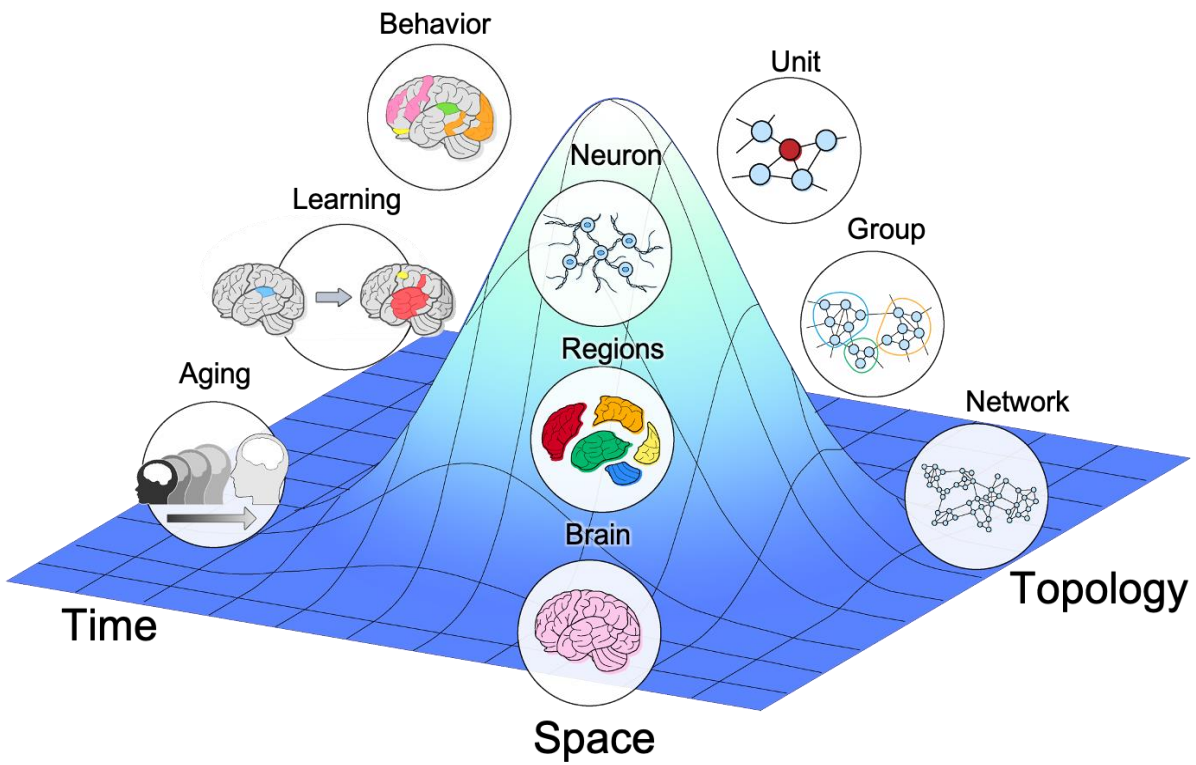
2. Graph analysis and modeling

- Filtering information in brain networks
  De Vico Fallani et al, PloS comp Biol, 2017
- Robust detection of network properties
  De Vico Fallani et al, PRE, 2014

3. New characterization of brain diseases

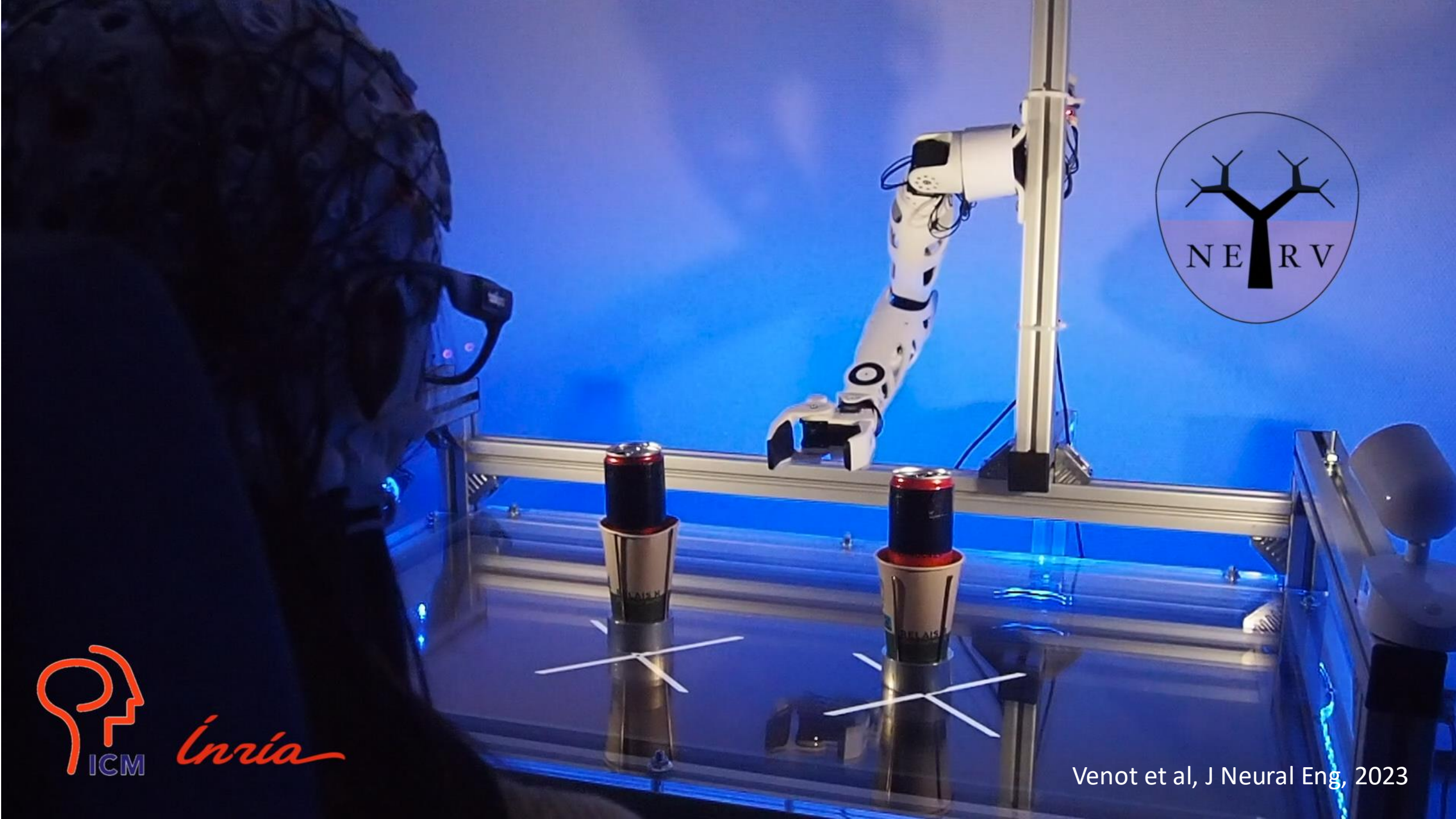
- Integration/segregation in stroke recovery
  Obando et al, J R Soc Interface, 2022
- Core-periphery structure in Alzehimer's
  Guillon et al, Netw Neurosci, 2019

Complex systems science for multiscale networks



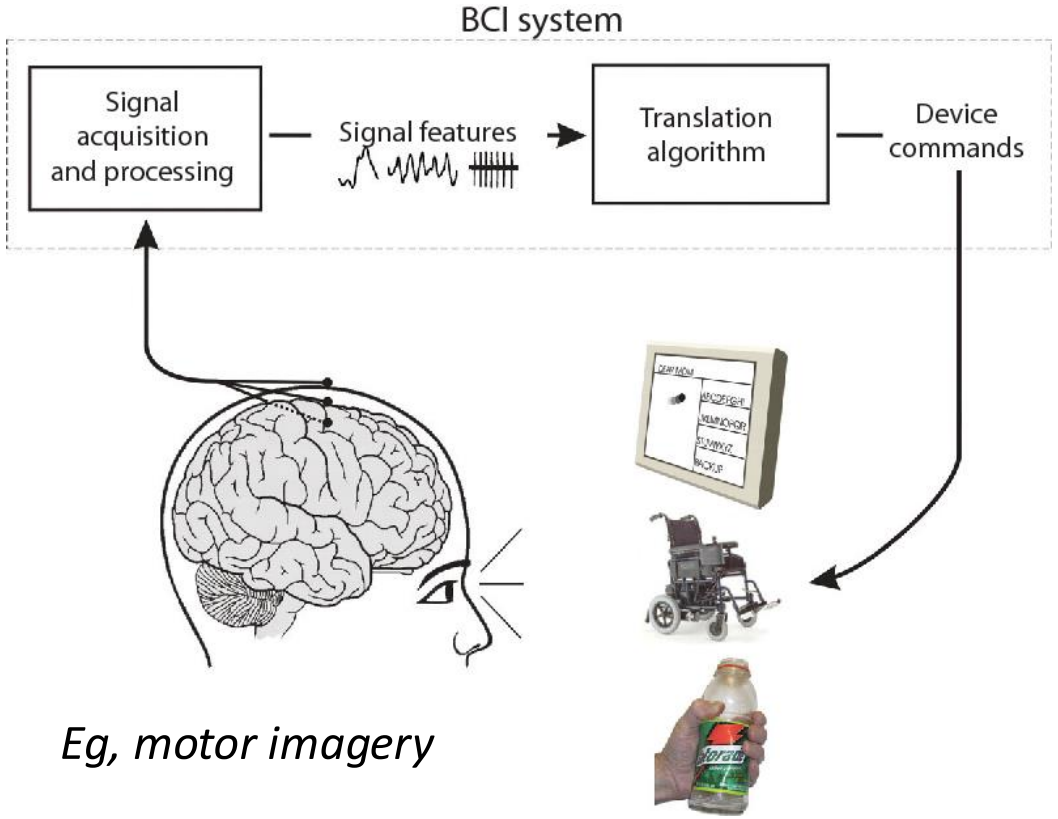
Presigny & De Vico Fallani, Reviews Modern Physics, 2023

- **Network dynamics**
  - Temporal networks
    Dichio et al, Phys Rev Lett, 2023
  - Network controllability
    Ben Messaoud et al, PLoS Comp Biol, 2024
- **Network structure**
  - Multilayer networks
    Presigny et al, Nat Comm, 2024
  - Network embedding
    Longhena et al, Phys Rev E, 2025
- **Multimodal networks**
  - ML fusion & nonlinearity
    Corsi et al, IEEE TBME, 2022
  - Brain-heart interactions
    Candia-Rivera et al, IEEE RBME, 2025



Venot et al, J Neural Eng, 2023

Noninvasive brain-computer interfaces (BCIs)



Eg, motor imagery

From Chaudary et al, Nat Rev Neurol, 2016

Great potential for **clinical applications**

- Real-time decoding → Assistive BCIs
- Neural plasticity → Rehabilitative BCIs

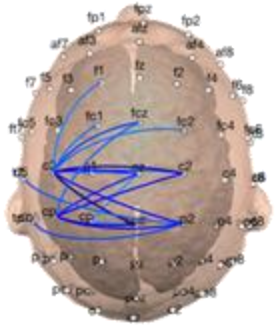
Problem : Current BCIs fail to detect the mental intentions in 20-50% of users

Why ? Overlook of interconnected nature of brain functioning

De Vico Fallani & Bassett, Phys Life Rev, 2019

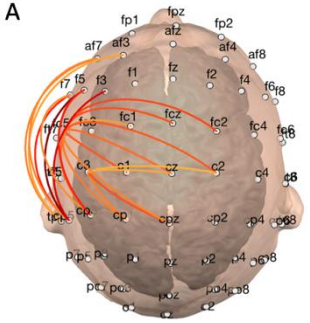
Role of brain networks in BCIs

Engineer the features space

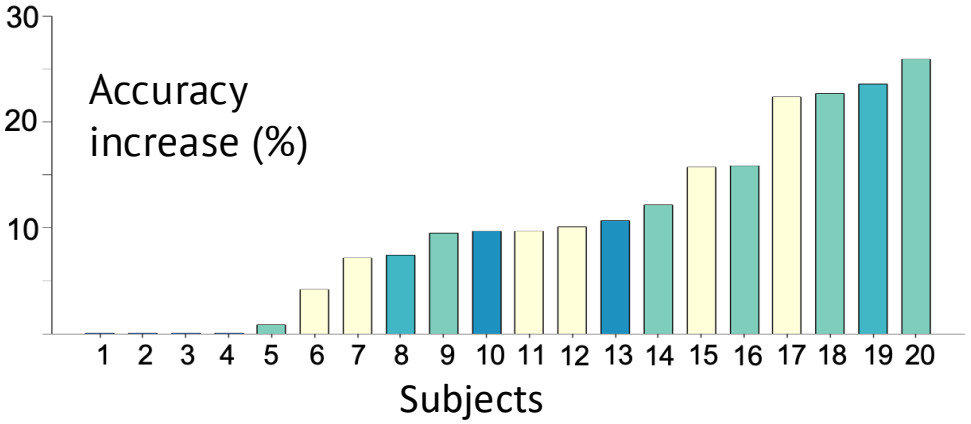


Amplitude Synchronization

+

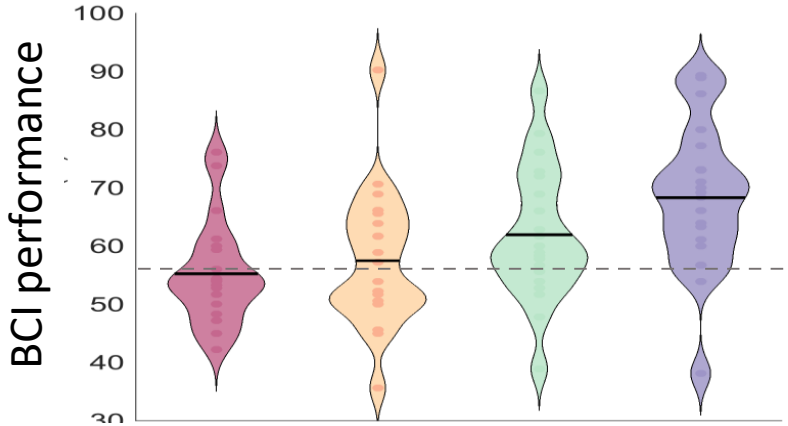


Phase Synchronization



Cattai et al, IEEE TNSRE, 2021

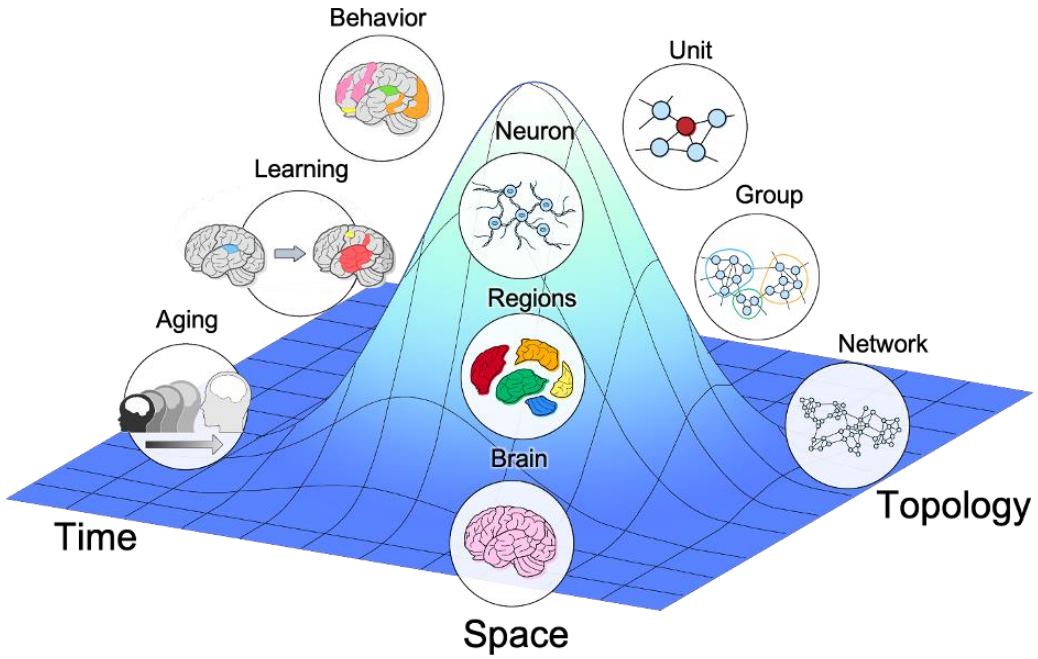
Better understand BCI learning



Progressive disconnection of attentional areas

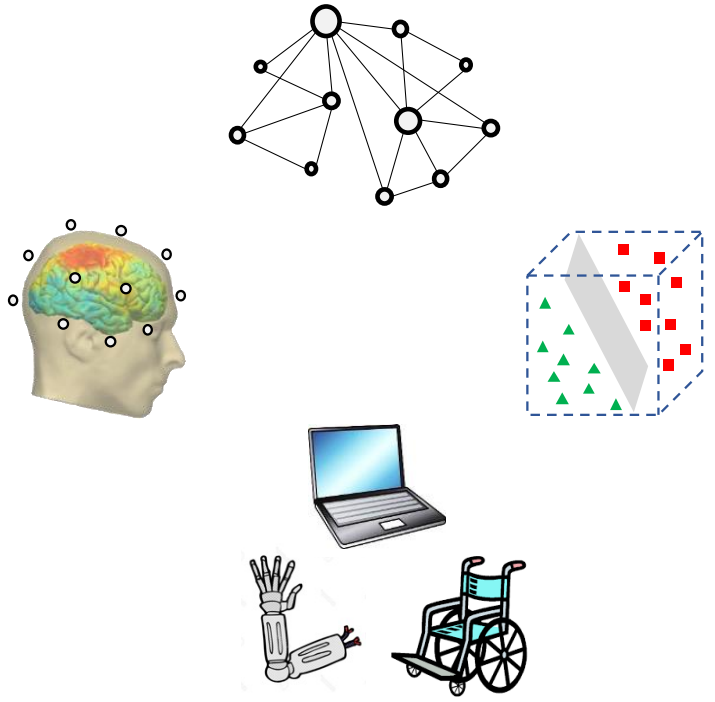
Corsi et al, Neuroimage, 2020

Complex systems



Overcome main limitations in current network neuroscience

Brain-computer interfaces



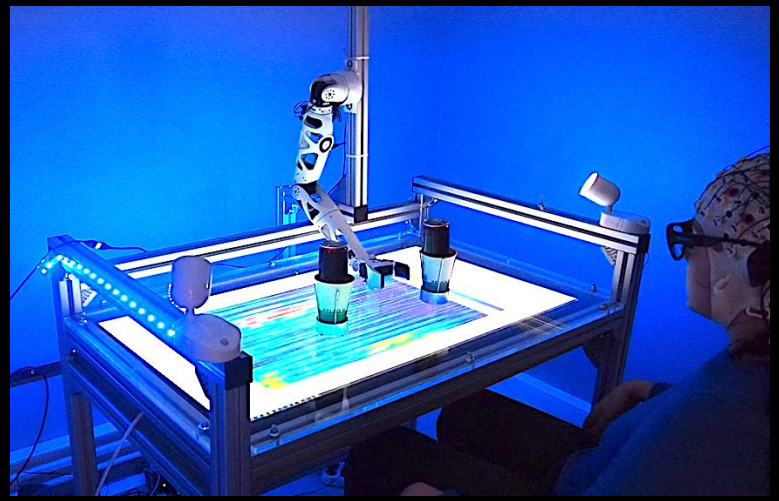
Design a new generation of efficient noninvasive BCIs

Technology, experiments and software




Augmented BCI platform

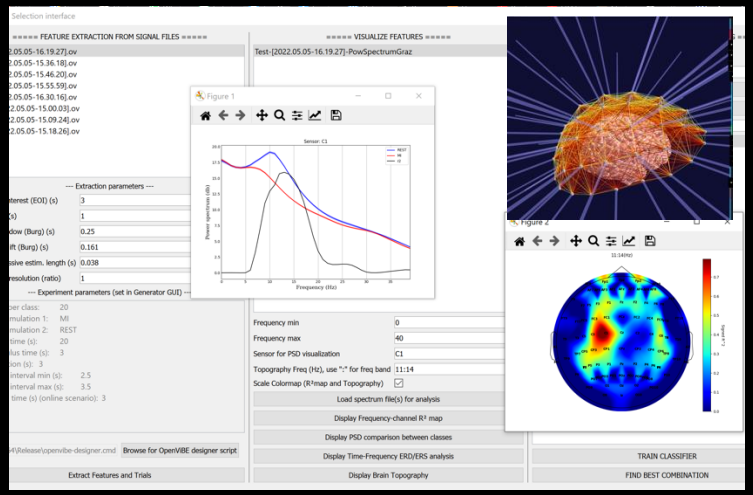
CENIR MEG-EEG core facility



PhDs: T Venot, C Bousfiha

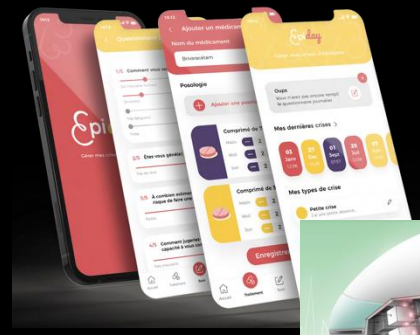
Interactive software

***HappyFeat**, Vizaj*



SW engineers: A Desbois, T Rolland

Portable solutions



Smart. Apps

OPM-MEG sensors

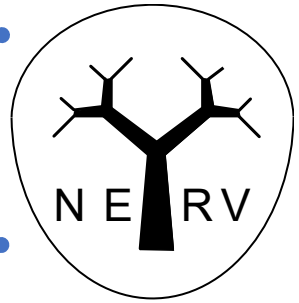
Collab DSI ICM, Ass. Generali

Multidisciplinary collaborations

Complex systems
- V Latora (Queen Mary)
- D Bassett (Penn Univ)

Cognitive/comput. neuroscience
- L Cohen (ICM)
- N George (ICM)
- V Jirsa (CNRS)

Systems neuroscience
- A Bacci (ICM)
- P Bartolomeo (ICM)
- M Corbetta (Padova Univ)



Rehabilitation/robotics
- L Saint-Bauzel (ISIR Lab)
- F Colle (St. Maurice Clinic)
- E Bayen, Rehab unit)

Neuromodulation
- A Valero-Cabre (ICM)
- JC Lamy (ICM)

Hospital/Clinics
- C Rosso (Stroke unit)
- V Navarro (Epilepsy unit)
- M Vidailhet (Parkinson unit)

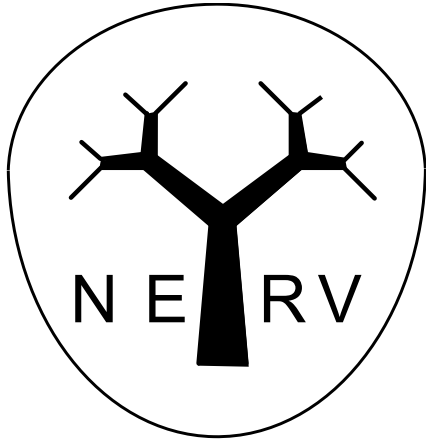
■ External ■ Local


Centre hospitalier
Sainte-Anne


GENERALI


Ramsay Santé
Clinique
du Bourget


Physio
St-Maurice
CLINIQUE INTERDISCIPLINAIRE


NERV


Air Liquide


IBM


ASSISTANCE
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DE PARIS


THALES


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NSF


PROJET FINANCÉ PAR L'ANR
ANR
PROJECT FUNDED BY THE ANR


INVESTISSEMENTS
D'AVENIR


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