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2025 *Activity Report*

RESEARCH CENTRE: **Inria Paris Centre at Sorbonne University**
IN PARTNERSHIP WITH: **CNRS, INSERM, Sorbonne Université**

Project-Team

NERV

Systems neuroengineering to model and interface brain networks

In collaboration with Institut du Cerveau et de la Moelle Epinière

Project-Team NERV

Creation of the Project-Team: 2023 October 01

Each year, Inria research teams publish an Activity Report presenting their work and results over the reporting period. These reports follow a common structure, with some optional sections depending on the specific team. They typically begin by outlining the overall objectives and research programme, including the main research themes, goals, and methodological approaches. They also describe the application domains targeted by the team, highlighting the scientific or societal contexts in which their work is situated. The reports then present the highlights of the year, covering major scientific achievements, software developments, or teaching contributions. When relevant, they include sections on software, platforms, and open data, detailing the tools developed and how they are shared. A substantial part is dedicated to new results, where scientific contributions are described in detail, often with subsections specifying participants and associated keywords. Finally, the Activity Report addresses funding, contracts, partnerships, and collaborations at various levels, from industrial agreements to international cooperations. It also covers dissemination and teaching activities, such as participation in scientific events, outreach, and supervision. The document concludes with a presentation of scientific production, including major publications and those produced during the year.

Keywords

Computer sciences and digital sciences

A5.1.4. – Brain-computer interfaces, physiological computing

A5.2. – Data visualization

A5.9. – Signal processing

A6.1. – Methods in mathematical modeling

A6.4.3. – Observability and Controlability

A8.8. – Network science

A9.3. – Signal processing

Other research topics and application domains

B1.2. – Neuroscience and cognitive science

B2.1. – Well being

B2.2. – Physiology and diseases

B2.5. – Handicap and personal assistances

B2.6. – Biological and medical imaging

B5.10. – Biotechnology

B9.5. – Sciences

Contents

1 Team members, visitors, external collaborators

Research Scientists

- Fabrizio de Vico Fallani [Team leader, INRIA, Senior Researcher, HDR]
- Mario Chavez [CNRS, Senior Researcher, HDR]
- Marie-Constance Corsi [INRIA, Researcher]

Faculty Member

- Laurent Bougrain [UL, Associate Professor Delegation]

Post-Doctoral Fellows

- Diego Candia Rivera [ICM]
- Andrea Civilini [INRIA, Post-Doctoral Fellow, from Jun 2025]
- Tristan Venot [INRIA, until Sep 2025]

PhD Students

- Bruno Aristimunha Pinto [INRIA, Co-supervised]
- Camile Bousfiha [INRIA, Co-supervised]
- Cassandra Dumas [ICM, Co-supervised]
- Baptiste Fague [ESSILOR, CIFRE, from Oct 2025]
- Marc Fiammante [SORBONNE UNIVERSITE]
- Jules Gomel [INRIA Saclay, ISAE Supaero, Co-supervised]
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- Marion Pavaux [THALES, CIFRE]
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Technical Staff

- Celestine Allombert-Blaise [ICM, Engineer, from Sep 2025]
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- Laurent Hugueville [CNRS, Engineer, 20%]
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- Marion Couton [SORBONNE UNIVERSITE, Intern, until Jun 2025]
- Linon Denis [ICM, Intern, from Oct 2025]
- Francesco Farina [INSERM, Intern, from Feb 2025 until Jul 2025]
- Camille Gabot [ICM, Intern, until Jul 2025]
- Pierre-Baptiste Mathieu De Carvalho [Loria, Intern, from Apr 2025 until Sep 2025]
- Laura Pitti [INSERM, Intern, from Sep 2025]
- Mario Roca [INSERM, Intern, from Feb 2025 until Aug 2025]
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Administrative Assistant

- Helene Milome [INRIA]

Visiting Scientist

- Giovanni Messuti [Università degli Studi di Salerno, from Nov 2025, PhD Student]

2 Overall objectives

NERV is an Inria project-team joint with the Paris Brain Institute (ICM) at the Pitié-Salpêtrière hospital (AP-HP) in Paris. NERV was created as a project-team in 2023 and later became team at the Paris Brain Institute (ICM) in 2025. NERV has a joint affiliation to Inria, CNRS, Inserm and Sorbonne University.

NERV is thus located both within a leading neuroscience institute and within a large hospital. This unique position has several advantages: direct contact with neuroscientists and clinicians allows us to foresee the emergence of new problems and opportunities for new methodological developments, provides access to unique datasets and experimental platforms, and eases the transfer of our results to clinical research and clinical practice.

Our broad goal is to consider brain-behavior problems at the intersection of statistical physics, biomedical engineering, and clinical neurosciences, that can be tackled using complex systems theory. To this end, we propose to create a new team focused on **systems neuroengineering**, developing new analytical tools and technologies to image, decode, and modulate the brain in order to comprehend its functions and to repair its dysfunction. Specifically, our team will tackle two main scientific thrusts in the next five years:

1. **Analyzing, modeling and controlling multiscale brain networks**. Our ambition is to better understand the structural and functional organization of the human brain. To this end, we propose new computational frameworks to characterize the spatio-temporal complexity of brain networks from multimodal (e.g. structural or functional) and longitudinal neuroimaging data.

2. **Designing a new generation of noninvasive brain-computer interfaces** (BCIs). There is a critical need to improve the usability of BCIs. Our original approach consists in introducing network methods into the BCI pipeline to better decode the user mental state, model the skill acquisition process, and reinforce mental intention-related brain patterns via neuromodulation.

The methodological and technological developments resulting from these goals, will be mainly applied to brain diseases, in close collaboration with neuroscientists and clinicians, in order to: i) provide new insights into the associated neural reorganizational processes ii) identify network-based biomarkers of disease and outcome and, iii) propose innovative network-based BCI neurorehabilitation strategies.

Thanks to the close interaction with ICM, which physically hosts the NERV team, we aim to play a major role in the complex systems and BCI community by capitalizing on the collaboration with other Inria/ICM teams and clinical units, as well as on technological transfer of our scientific expertise to the development of med-tech products.

3 Research program

The NERV project-team has a two-fold reserch trhust. On one hand, it develops methods from signal processing, complex systems, network science, to model and analyze the interconnected nature of the nervous system. On the other hand, it developes noninvasive brain-computer interfaces to allow humans interacting with the external world using brain activity.

3.1 Analyzing, modeling and controlling multiscale brain networks

3.1.1 Multilayer analysis of multimodal brain networks

As in many other real complex systems, the type of interactions between the regions of a same brain might be of different nature, this giving rise to multiple networks between the same nodes (eg, structural, functional, etc). Despite such one-to-many relationship, common network approaches have been traditionally conceived to analyze and model one single type of connectivity. Our project-team develops novel network approaches to the case of multiple interconnected systems. We specifically focus on the development of methods based on multilayer network theory to fully exploit the rich multimodal nature of brain networks.

3.1.2 Temporal models of dynamic brain networks

Current approaches in network neuroscience assume static or time-invariant network that could not capture dynamical mechanisms, such as the persistence or formation of specific connectivity patterns, which are instead crucial in time-varying networks. Another crucial limitation is that standard approaches are basically data-driven, so that the obtained network indices lack of confidence intervals thus making difficult the generalization of the observed results. NERV proposes to simultaneously overcome these limitations by introducing novel model-based approaches that support statistical inference on the connection mechanisms underlying the observed time-varying networks.

3.1.3 Theoretic controllability of brain networks

Controllability of networks refers to the possibility of driving the current state of a system to a specific final state by means of external control inputs. While encouraging results have been obtained in brain networks this field remains quite largely unexplored. How expensive is to drive brain states? Can brain networks be steered effectively from few nodes? What type of input signal should be used? Our project-team addresses the above questions and provide a more robust framework that can be used to identify intervention strategies facilitating desired behavior (eg, learning, Stroke recovery) and counteracting clinical conditions (eg Alzheimer's disease, epilepsy).

3.1.4 Latent geometry of brain networks

Brain networks are a special type of networks embedded in a physical space, so that geometric network models, taking into account distance as a costly factor in links formation, appear particularly relevant. However, the existence of a possible latent structure behind the observed brain network properties is still poorly understood. Is there a hidden geometry model that can explain the observed connectivity? Our project-team explores non-Euclidean geometries to represent complex brain networks and unveil hidden structural properties of the system in a complementary and coherent way. We apply these models to understand and unveil network mechanisms in brain diseases across multiple scales.

3.2 Designing a new generation of efficient noninvasive BCIs

3.2.1 Enriching the features space of BCIs with multimodal brain network metrics

The research of alternative features for improving BCI performance has been quite limited and rather crude univariate features, such as frequency band power or time point concatenation of the brain signals, have been typically used. However, the information contained in brain signal interactions across multiple physiologically-relevant frequency bands has been surprisingly neglected. NERV aims to improves BCI performance by enriching the feature space by inlcuding brain connectivity and network metrics. The project-team develops and text experimentally these advances in both healthy and diseased subjects.

3.2.2 Informing adaptive BCIs through generative network models of human learning

In a BCI, both the human and the computer are part of the same system. In such co-adaptive environment, it is paramount that the computer could adapt to the physiological nonstationarity of the brain features. However, classification algorithms should adapt in practice when the user is in the loop still need to be clarified. NERV develops new statistical network models to characterize temporally dynamic brain networks. By building these new models, we first identify the dynamic brain network properties that significantly predict with the BCI skill acquisition. Once identified, these features will be used to design innovative BCI architectures that take into account the dynamics associated with the user's learning in an effort to improve the overall performance.

3.2.3 Boosting BCI performance through targeted brain stimulation

While richer brain features and an enhanced understanding of the process of learning itself may enhance BCI accuracy on average, challenges still remain for single individuals. An alternative approach is to draw on recent advances in noninvasive brain stimulation technology, such as transcranial magnetic stimulation (TMS), which can directly influence the brain plasticity by sending an external signal that interfere locally and alter the internal neural dynamics. NERV aims to leverage theoretical network controllability models to experimentally validate the ability of single brain regions to steer target brain areas towards BCI-related spatiotemporal activity. By means of this approach, we aim to identify which brain areas and what type of input signal is needed to favor BCI-related plasticity and improve performance of individual subjects.

3.2.4 Towards multimodal and augmented noninvasive BCIs

While BCI performance has been mainly thought as a classification or features extraction issue, current evidence suggests that many other factors can actually affect the accuracy of the system. Among others, the use of alternative physiological signals (ECG, EMG among others), can influence the motivation of the subjects, their sense of agency and in turn their performance. Our project-team develops complementary approaches based on hybrid signal control and enriched feedbacks, to create immersive and ecological BCI setups in an effort to further ameliorate the BCI performance. This activity also explores a new technology based on optically pumped magnetometers to have more accurate brain signals.

4 Application domains

Our methodological and technological development will be mainly applied to solve neuroscience-related problems that can be tackled using systems-level approaches. In line with the Inria challenges plan, our project-team will contribute to modeling and simulation for digital health. Thanks to the strategic position within ICM, we will also design and perform innovative experimental protocols to gather data in humans and validate our theoretical outcome and tools. To this end, we will capitalize on our long-lasting expertise in experimental data acquisition and protocol validation from national and international ethical committees (eg, NIH, CPP, CNRS, Inserm, Coerle). In addition, we can rely on a unique access to large cohorts of patients (eg, INSIGHT cohort for Alzheimer's patients, stroke and epileptic patients from the clinical units at the hospital) which can significantly contribute to the statistical value of our discoveries.

4.1 Network-based biomarkers of brain diseases

Accumulating evidence indicates that the symptoms of a neurological disease are often associated with an abnormal organization of the connections in the brain. Network science and complex systems theory provide therefore natural tools to analyze and model brain diseases as well as to identify pathological reorganizational mechanisms. Our project-team will specifically focus on:

- **Stroke** is a medical condition in which parts of the brain die due to blood supply cut-offs, thus leading to motor-cognitive impairments associated with the dead zone. Predicting the impact of a brain damage and the ability of patients to restore their lost functions is a major issue in stroke neuroscience. Because the brain is an interconnected system, stroke damages -which are local- will also have effects on the rest of the network and induce global reconfiguration processes. By introducing original analytical and modeling tools, we aim to better understand neural plasticity after stroke and derive brain network signatures of functional recovery at individual level. To this end, we already collaborate with the Stroke Unit at the Pitie-Salpetriere Hospital (PU-PH C Rosso) and with P Bartolomeo (INSERM DR) who is a renowned expert in clinical neuroscience at ICM.

  While the NERV team will focus on stroke, it will continue the ongoing collaborations to terminate projects related to:

- **Epilepsy** is a group of neurological disorders characterized by recurrent epileptic seizures, which can range from brief, often imperceptible events to prolonged episodes of intense convulsive activity caused by abnormal electrical discharges in the brain. The detection of epileptic seizures, the prediction of their onset, and the identification of the most effective pharmacological treatment for individual patients represent critical challenges from both fundamental and clinical perspectives. In our research works, we address these challenges by adopting an original framework based on network science, aiming to improve our understanding of the role of underlying brain connectivity in the generation and propagation of seizures and to identify more accurate and reliable biomarkers. To this end, we benefit from established collaborations with the Epilepsy Unit at the Pitie-Salpetriere Hospital (PU-PH V Navarro) and with the Universitary Hospital, in Strasbourg (MCU-PH V Dinkelacker).

- **Neurodegeneration** is caused by the progressive loss of structure or function of neurons, which leads to a range of cognitive and motor impairments, from mild to severe, and eventually to death. Most of research currently focuses on predicting as soon as possible those individuals who will develop the disease, so as to adopt the best therapeutics and slow the disease progression. By adopting a network perspective, we aim to understand the abnormal reorganizational connection processes behind the disease and provide alternative biomarkers that can be integrated with existing ones (eg atrophy, behavioral, metabolic) to improve the accuracy prediction. To this end, we already collaborate with the ARAMIS team and with the Experimental Neurosurgery team at ICM (Parkinson, B Lau CRNS and C Karachi MCU-PH) and we have long-lasting collaborations with the Institut de la memoire et de l Alzheimer (IM2A) at the Pitie-Salpetriere hospital (PU-PH Prof B Dubois).

4.2 Improving BCI efficiency for clinical applications

Enhancing the accuracy of the BCI performance not only has a fundamental interest, but it also has practical consequences. Better decoding the user's mental intent means better understanding the underlying neural process and transform it in more reliable external commands. Our project-team aims to unlock BCI clinical applications by specifically unveiling new network connectivity features of brain functioning. We'll specifically focus on:

- **Neuromotor rehabilitation** aims to aid recovery from a nervous system injury (eg, stroke, Parkinson) and to minimize/compensate for motor alterations resulting from it. Identifying the best rehabilitation strategy for each patient is a major challenge as it significantly affects the quality of recovery. By developing high-performance BCI prototypes we aim to introduce innovative intervention strategies that ease the neuromotor recovery process through noninvasive neurofeedback experimental protocols. To this end, we already collaborate with the Experimental Neurosurgery team at ICM for the application to Parkinson's subjects (ANR Betapark) and we are in the process of establishing new collaborations,

within the ERC BCINET, with important stroke neurorehabilitation units at the Pitie-Salpetriere Hospital (P Pradat, AP-HP) and at the Saint-Maurice Hospital (F Colle, AP-HP).

While the NERV team will focus on Neuromotor rehabilitation, it will continue the ongoing collaboration to terminate projects related to:

- **Brain monitoring** aims to detect events associated with mental states that emerge from background ongoing brain activity (eg, stress or epileptic dynamics). The accuracy of their detection is crucial to decide and execute the most appropriate action from the computer. Our project-team aims to fine-tune and optimize the innovative BCI prototypes for real-time target applications. To this end, we already have collaborated with Air Liquide Medical Systems and the Pitié-Salpêtrière Hospital (Intensive Care Units, PU-PH T Similowski, M Raux), for the development of an EEG-based BCI which detects respiratory discomforts in ventilated patients (patent WO 2013/164462). Also, we have consolidated collaborations with the start-up Mybraintech (ICM spin-off) to develop portable BCIs for predicting mental stress (CIFRE partnership), and with IBM-France and Armand-Troussaud hospital (MD-PH AI Vermersch) to develop EEG-based aid diagnostics tool for predicting newborn hypoxia.

- **Assistive technology** is used to increase or maintain the functional capabilities of disabled people (eg, wheelchairs, prostheses). Assistive BCIs represent therefore a promising tool for allowing users to control external devices directly with their brain. Although our project-team is more focused on rehabilitative BCIs, the development of high-performance BCIs can unlock assistive BCI applications, too. To this end, we have recently started a collaboration with the ISIR lab (LIP6) for the design of a multimodal BCI prototype that controls a robotic arm and grab objects in a 3D space (PhD T Venot). We next aim to integrate augmented reality and enriched feedbacks (virtual hands) to render more ecological environments and improve the sense of agency of patients.

5 Highlights of the year

5.1 Awards

- Marie-Constance Corsi received the Early Career Award by the BCI Society
- Marc Fiammante received the Prix Félix Innovateur from Central Supélec Alumni

5.2 Startup

- Marc Fiammantewas accepted at the “Pepinière Paris Santé” program of the Cochin Hospital (Paris) to create his startup, focused on neonatal brain monitoring.
- Tristan Venot joined the Inria Startup Studio program to create the startup Cirus, focusing on brain-computer interfaces.

6 Latest software developments, platforms, open data

6.1 Latest software developments

6.1.1 HappyFeat

Keywords: BCI, Connectivity, Brain-Computer Interface, Classification, GUI (Graphical User Interface), Signal processing, Biomedical data

Scientific Description: Two main use-cases are targeted: - Using MI in a clinical setting (e.g. stroke rehabilitation), by greatly reducing the risks of mistakes during the offline analysis and the time needed to perform this step, quickly bridging the gap between EEG data acquisition and online BCI usage.

- Exploring new, alternative metrics for discriminating between mental states. To this aim, prototypes for prospective methods need to be validated on signal databases, before moving on to experimental

conditions. HappyFeat helps bridging this gap, and provides a framework in which such methods can be tested, after implementation.

The targetted audience is therefore on the one hand clinicians, neurophysiologists and neuroscientists who want to use BCI in their programs, but also the research community in BCI, brain networks, and functional connectivity.

Functional Description: Brain Computer Interfaces (BCI) has a strong potential in clinical applications such as post-stroke rehabilitation. However, in such constrained contexts, obtaining satisfactory performances from a BCI system can be a challenging task, mainly due to the need for fine-tuning the classification algorithm used to distinguish between mental tasks. Training the classification algorithm with adequately selected features obtained from spectral analysis or other alternative metrics is crucial.

HappyFeat is a software assistant for feature extraction and selection in BCI. It proposes a trial-and-error oriented workflow, where experimenters can extract, visualize and select features of interest for training as many times as needed, in a short time, until a satisfying classification training accuracy is reached.

Every operation from signal loading and feature extraction to classifier training is handled from a unified, dashboard-like GUI, removing the need to use different softwares for data acquisition, feature analysis, classifier training and online classification, and to manage data formatting across the different environments.

Along with the commonly used Power Spectral Density (PSD), HappyFeat enables to work with Functional Connectivity, allowing to use novel network-based approaches based on recent research.

HappyFeat uses OpenViBE in the background for the extraction and training parts, as a fast and efficient processing engine, taking advantage of its optimized C++ implementation of signal processing methods. The generation and manipulation of use-case scenarios is entirely automated via scripts and templates, removing the inherent risk of mistakes in a time constrained environment.

HappyFeat puts the emphasis on reproducibility, by keeping track of all manipulations (EEG sessions file lists, signal processing, classification attempts) and allowing to save, load and export previous work.

Release Contributions: - Support for Timeflux, with a 2-class MI protocol based on PSD (with Welch's method) - Tutorial for newcomers, using Timeflux - Dependencies can be installed with conda - Python 3.12.8, dependencies update - Parameters for the AutoFeat mechanism can be set via menus - Most visualization tools use plotly, and figures are saved in the workspace

- GUI fixes - Templates updated - Fixed various crash sources & stability issues

URL: https://github.com/Inria-NERV/happyFeat

Publication: hal-03842568v1

Contact: Arthur Desbois

Participants: Arthur Desbois, Marie-Constance Corsi, Fabrizio De Vico Fallani

6.1.2 VIZAJ

Name: A free online interactive software for visualizing spatial networks

Keywords: Complex Systems, Data visualization

Functional Description: In many fields of science and technology we are confronted with complex networks. Making sense of these networks often require the ability to visualize and explore their intermingled structure consisting of nodes and links. To facilitate the identification of significant connectivity patterns, many methods have been developed based on the rearrangement of the nodes so as to avoid link criss-cross. However, real networks are often embedded in a geometrical space and the nodes code for an intrinsic physical feature of the system that one might want to preserve. For these spatial networks, it is therefore crucial to find alternative strategies operating on the links and not on the nodes. Here, we introduce Vizaj a javascript web application to render spatial networks based on optimized

geometrical criteria that reshape the link profiles. While optimized for 3D networks, Vizaj can also be used for 2D networks and offers the possibility to interactively customize the visualization via several controlling parameters, including network filtering and the effect of internode distance on the link trajectories. Vizaj is further equipped with additional options allowing to improve the final aesthetics, such as the color/size of both nodes and links, zooming/rotating/translating, and superimposing external objects. Vizaj is an open-source software which can be freely downloaded and updated via a github repository. Here, we provide a detailed description of its main features and algorithms together with a guide on how to use it. Finally, we validate its potential on several synthetic and real spatial networks from infrastructural to biological systems. We hope that Vizaj will help scientists and practitioners to make sense of complex networks and provide aesthetic while informative visualizations.

URL: https://bci-net.github.io/vizaj/

Publication: hal-03837671v2

Contact: Fabrizio De Vico Fallani

6.2 New platforms

6.2.1 Noninvasive brain-computer interfaces (BCI)

Participants: Marie-Constance Corsi, Arthur Desbois, Tristan Venot, Laurent Bougrain, Laurent Hugueville, Fabrizio De Vico Fallani *(Correspondant)*.

NERV coordinates the research and development activity of the Brain-Computer Interface (BCI) platform at the Centre EEG/MEG of the neuroimaging core facility of the ICM. The R&D activity consists in assembling, testing different hardware, software developments to ensure the highest reliability and performance, as well as to test innovative technological solutions. Several projects, including our NETBCI NIH/ANR, MANET ANR-JCJC, and ATTACK Big-brain theory funded projects, as well as experiments by different researchers of the Institute (ANR BETAPARK Project), and the BCINET ERC Consolidator grant (F De Vico Fallani) are currently being run.

The BCI experimental platform is closely linked to the development of the Happyfeat software by our engineer A. Desbois (see Software section). HappyFeat is part of a larger INRIA BCI software suite together with OpenVibe (HYBRID team) and BCIVizApp (CHRONOS Temporal). HappyFeat allows to easily intergate new functionalities based on our methodological development on brain connectivity networks and integrates efficient graphical user interfaces for easy use by clinicians.

7 New results

7.1 Low-dimensional controllability of brain networks

Participants: Remy Ben Messaoud, Camile Bousfiha, Marie-Constance Corsi, Mario Chavez, Fabrizio de Vico Fallani *(Correspondant)*.

Identifying the driver nodes of a network has crucial implications in biological systems from unveiling causal interactions to informing effective intervention strategies. Despite recent advances in network control theory, results remain inaccurate as the number of drivers becomes too small compared to the network size, thus limiting the concrete usability in many real-life applications. To overcome this issue, we introduced a framework that integrates principles from spectral graph theory and output controllability to project the network state into a smaller topological space formed by the Laplacian network structure. Through extensive simulations on synthetic and real networks, we showed that a relatively low number of projected components can significantly improve the control accuracy. By introducing a new low-dimensional controllability metric we experimentally validated our method on N = 6134 human connectomes obtained from the UK-biobank

cohort. Results revealed previously unappreciated influential brain regions, enabled to draw directed maps between differently specialized cerebral systems, and yielded new insights into hemispheric lateralization. Taken together, our results offered a theoretically grounded solution to deal with network controllability and provided insights into the causal interactions of the human brain.

More details in [5].

7.2 Interpretability of Riemannian tools used in brain computer interfaces

Participants: Tristan Venot, Marie-Constance Corsi *(Correspondant)*.

Riemannian methods have established themselves as stateof-the-art approaches in Brain-Computer Interfaces (BCI) in terms of performance. However, their adoption by experimenters is often hindered by a lack of interpretability. In this work, we propose a set of tools designed to enhance practitioners' understanding of the decisions made by Riemannian methods. Specifically, we develop techniques to quantify and visualize the influence of the different sensors on classification outcomes. Our approach includes a visualization tool for high-dimensional covariance matrices, a classifieragnostic tool that focuses on the classification process, as well as methods that leverage the data's topology to better characterize the role of each sensor. We demonstrate these tools on a specific dataset and provide Python code to facilitate their use by practitioners, thereby promoting the adoption of Riemannian methods in BCI.

More details in [31].

7.3 Automatic Ocular Artifact Correction in Electroencephalography for Neurofeedback

Participants: Cassandra Dumas, Marie-Constance Corsi *(Correspondant)*.

Ocular artifacts can significantly impact electroencephalography (EEG) signals, potentially compromising the performance of neurofeedback (NF) and brain-computer interfaces (BCI) based on EEG. This study investigates if the Approximate Joint Diagonalization of Fourier Cospectra (AJDC) method can effectively correct blink-related artifacts and preserve relevant neurophysiological signatures in a pseudo-online context. AJDC is a frequency-domain Blind Source Separation (BSS) technique, which uses cospectral analysis to isolate and attenuate blink artifacts. Using EEG data from 21 participants recorded during a NF motor imagery (MI) task, we compared AJDC with Independent Component Analysis (ICA), a widely used method for EEG denoising. We assessed the quality of blink artifact correction, the preservation of MI-related EEG signatures, and the influence of AJDC correction on the NF performance indicator. We show that AJDC effectively attenuates blink artifacts without distorting MI-related beta band signatures and with preservation of NF performance. AJDC was calibrated once on initial EEG data. We therefore assessed AJDC correction quality over time, showing some decrease. This suggests that periodic recalibration may benefit long EEG recording. This study highlights AJDC as a promising real-time solution for artifact management in NF, with the potential to provide consistent EEG quality and to enhance NF reliability.

More details in [37].

7.4 Riemannian fusions of EEG-based features for motor imagery detection under propofol sedation

Participants: Camilla Mannino, Marie-Constance Corsi, Laurent Bougrain *(Correspondant)*.

The brain is a complex system requiring multimodal approaches to better understand cognitive or motor functions. Thus, different and complementary electroencephalographic (EEG) neurophysiological features

are available at various spatial, frequency, and temporal scales, e.g., brain connectivity, complexity, or entropy. However, they are usually not investigated all together. In this study, we combine and compare five EEG-based connectivity features with covariance matrices, defining five Riemannian fusion methods and three Euclidean ones as references. We do so for classifying motor imagery EEG signals, both in awake and sedated subjects, with the future goal of detecting accidental awareness during general anesthesia. Covariance matrices alone yielded the best accuracy, with and without sedation. Phase-based connectivity estimators appear to be the most promising fusion with covariances. No significant differences were found between the best fusion of features and that of classifiers.

More details in [30].

7.5 Linking heartbeats with the cortical network dynamics involved in self-social touch distinction

Participants: Fabrizio De Vico Fallani, Diego Candia-Rivera *(Correspondant)*.

Research on interoception has revealed the role of heartbeats in shaping our perceptual awareness and embodying a first-person perspective. These heartbeat dynamics exhibit distinct responses to various types of touch. We advanced that those dynamics are directly associated to the brain activity that allows self-other distinction. In our study encompassing self and social touch, we employed a method to quantify the distinct couplings of temporal patterns in cardiac sympathetic and parasympathetic activities with brain connectivity. Our findings revealed that social touch led to an increase in the coupling between frontoparietal networks and parasympathetic/vagal activity, particularly in alpha and gamma bands. Conversely, as social touch progressed, we observed a decrease in the coupling between brain networks and sympathetic dynamics across a broad frequency range. These results show how heartbeat dynamics are intertwined with brain organization and provide fresh evidence on the neurophysiological mechanisms of self-social touch distinction.

More details in [13].

7.6 Assessment of a learner's mental state: search for EEG markers that can distinguish fluctuations in sustained attention and cognitive engagement

Participants: Pierre-Baptiste Mathieu de Carvalho, Marie-Constance Corsi, Laurent Bougrain *(Correspondant)*.

We aimed to establish the methodological foundations for distinguishing, using EEG, between sustained attention and cognitive engagement in a learning context. This preliminary work based on a large review made it possible to explore and test the relevance of the approach and the robustness of an experimental protocol approved by the Operational Committee for the Evaluation of Legal and Ethical Risks of Inria (COERLE 2025-66). The main finding of this study, a priori, lies in the heterogeneity of individual profiles: while attention mechanisms seem to follow a common logic, the way in which individuals engage cognitively appears to be a more personal strategy. This variability, which will need to be monitored on a larger sample, offers serious avenues for further research. Indeed, it suggests that the development of personalized approaches could be a promising alternative to the search for universal markers. Thus, by capturing the dynamics specific to each learner, this future work paves the way for the development of neuro-adaptive interaction loops, which will ultimately be able to assist learning more precisely or improve BCI control, as envisaged in the introduction.

More details in [45].

7.7 Median nerve stimulation to assess Motor Imagery-BCI performances

Participants: Laurent Bougrain *(Correspondant)*.

Motor Imagery-based Brain-Computer Interfaces (MI-BCIs) enable device control through ElectroEncephalOGraphy (EEG), yet intra- and inter-subject variability remains a critical challenge affecting system reliability. Median Nerve Stimulation (MNS) has emerged as a promising alternative motor task, but its variability characteristics and predictive value require systematic investigation. This study quantifies EEG variability in MNS-induced Event-Related Desynchronization (ERD) compared to MI, and evaluates MNS-ERD as a performance predictor using Linear Discriminant Analysis (LDA) and Least Absolute Shrinkage and Selection Operator (LASSO). Results demonstrate that MI elicits stronger ERD with lower intra-subject variability than MNS, while inter-subject variability remains comparable between tasks. For performance prediction, LDA and LASSO achieved 74% accuracy for two-group classification (low vs. high performers), with hierarchical clustering reaching 83% accuracy. Topographical analyses revealed enhanced motor cortex activation in high performers during both tasks. These findings establish MNS-induced ERD as a reliable, non-invasive predictor for early user stratification while providing quantitative insights into EEG variability patterns essential for personalized BCI design and applications including intraoperative awareness monitoring. Two workshops have been co-organized linked with this topic (see 10.1.1)

More details in [25, 27, 29].

7.8 Connectivity-based prediction of the surgery outcome in temporal lobe epilepsy

Participants: Martin Guillemaud, Mario Chavez *(Correspondant)*.

Epilepsy surgery is a key treatment for patients with drug-resistant temporal lobe epilepsy (TLE), yet predicting surgical outcomes remains challenging. We introduce a novel connectivity-based biomarker derived from structural brain network changes induced by surgery, analyzed using hyperbolic graph embeddings. Using structural and diffusion MRI data from 51 patients, we compared pre- and post-surgical connectivity networks and applied hyperbolic Poincaré disk embeddings to distinguish favorable from poor outcomes. The approach identified connectivity patterns in contralateral brain regions as potential biomarkers of surgical success. Model validation using leave-one-out cross-validation yielded an AUC of 0.86 and a balanced accuracy of 0.81, demonstrating strong predictive performance. These results highlight the potential of non-Euclidean network embeddings to improve personalized outcome prediction in TLE surgery.

More details in [21].

8 Bilateral contracts and grants with industry

8.1 Bilateral contracts with industry

8.1.1 CIFRE PhD - Reliev Technology

Participants: Mario Chavez *(Correspondant)*.

Partner : Startup Reliev Technology (Nantes)

Description : This project aims at developing a non-invasive multimodal system for predicting the risk of epileptic seizures, based on artificial intelligence, which will be integrated into a continuous monitoring system in patients allowing the acquisition in ambulatory mode.

Coordinator : Mario Chavez

Duration : 3 years

8.1.2 CIFRE PhD - Thales

Participants: Marion Pavaux *(Correspondant)*.

Partner : Thales (Paris-Saclay)

Description : Brain–Computer Interfaces (BCIs) create a direct link between brain activity, often recorded via EEG, and a computer. They are used for assistance, rehabilitation, and remote control, but their performance remains limited due to reliance on univariate brain measures. Analyzing brain connectivity networks shows promise, yet current methods are too computationally demanding for real-time use. This project explores deep learning architectures designed to produce universal, stable, and efficient EEG representations for real-time brain activity decoding.

Coordinator : Fabrizio De Vico Fallani

Duration : 3 years

8.1.3 CIFRE PhD - EssilorLuxottica

Participants: Baptiste Fague *(Correspondant)*.

Partner : EssilorLuxottica (Paris)

Description : This thesis project first aims to better understand the relationship between brain response and visual perception through cylindrical corrective lenses, a common optical device used to correct astigmatism. Secondly, leveraging advances in EEG technology, we aim to develop an automated method for determining an individual's refractive error by measuring only their brain response.

Coordinator : Marie-Constance Corsi

Duration : 3 years

9 Partnerships and cooperations

9.1 International initiatives

9.1.1 Participation in other International Programs

FACE Foundation - FR-US partnership

Participants: Marie-Constance Corsi.

Project title: Biophysical modeling to inform Brain-Computer Interface learning mechanisms

Partner: University of California, San Francisco (UCSF)

Date/Duration: 2 years

Amount: 20keuros

Coordinators: Parul Verma (formely postdoc at UCSF, now at IIT Madras, India), & Marie-Constance Corsi

Summary: BCI is a promising tool for patients who suffer from neuromuscular pathologies or lesions. Nevertheless, it fails to detect intents in 30% of the BCI users, even after several weeks of training. To circumvent it, it is crucial to better understand the mechanisms underlying the BCI training. In this project, we aim at using the spectral graph model (SGM) developed by the US project leader's lab to identify biophysical changes occurring while controlling a BCI. SGM captures the relationship between brain structure and brain function with a reduced number of interpretable parameters. We will apply SGM to a longitudinal BCI dataset collected by the French project leader. We will fully explore the potentiality of this approach to identify biophysical markers that inform the neural mechanisms underlying the BCI training. Such insights could pave the way to tailored BCI training programs.

9.2 International research visitors

9.2.1 Visits of international scientists

Other international visits to the team

Giovanni Messuti

PhD student

Institution of origin: Università degli Studi di Salerno

Country: Italy

Dates: from November 2025 to May 2026

Context of the visit: The project aims to leverage a multimodal framework integrating both EEG and MEG, which could (i) improve decoding accuracy in an interpretable way, and (ii) shed light on the neural mechanisms underlying the learning process during BCI training. This is the first attempt to use M/EEG data within a latent space framework to improve BCI classification and to study patterns that arise while learning to control a BCI system. This project marks the beginning of our collaboration with Prof. S. Scarpetta (Università degli Studi di Salerno) on the application of biophysics tools in neuroscience.

Type of mobility: Research stay

Correspondant: Marie-Constance Corsi

9.2.2 Visits to international teams

Research stays abroad

Laurent Bougrain

Visited institution: National University of Entre Ríos

Country: Argentina

Dates: 18-22 August 2025

Context of the visit: Collaboration on Brain-computer interfaces for stroke patients and transfer learning for future international calls

Mobility program/type of mobility: (sabbatical, internship, research stay, lecture. . .) Invited professor program from the National University of Entre Ríos

Laurent Bougrain

Visited institution: Kyushu Institute of Technology (Kyutech)

Country: Japan

Dates: 7-11 April 2025

Context of the visit: 2023-2025 Collaborative project Université de Lorraine on "Human/Robot Social Interactions: engagement and affect analysis during gaming tasks

Mobility program/type of mobility: Erasmus+ mobility

Tristan Venot

Visited institution: Kyushu Institute of Technology (Kyutech)

Country: Japan

Dates: 3-12 February 2025

Context of the visit: program for students

Mobility program/type of mobility: JST Sakura Science Program (Japan)

Pierre-Baptiste Mathieu de Carvalho

Visited institution: Kyushu Institute of Technology (Kyutech)

Country: Japan

Dates: 7-11 April 2025

Context of the visit: 2023-2025 Collaborative project Université de Lorraine on "Human/Robot Social Interactions: engagement and affect analysis during gaming tasks

Mobility program/type of mobility: 2023-2025 Collaborative project Université de Lorraine on "Human/Robot Social Interactions: engagement and affect analysis during gaming tasks

9.3 European initiatives

9.3.1 Horizon Europe

MSCA NETCORE

Participants: Diego Candia-Rivera *(Correspondant)*.

Project title: Biomarkers of the interplay between brain networks and cardiac dynamics for the evaluation of non-invasive brain-computer interfaces

Duration: 2024-2026

Amount: 212k€

Coordinator: DiegoCandia-Rivera

Otherpartners: ICM

Summary: Brain-computerinterfaces(BCI) hold promise in the restoration of lost sensorimotor abilities after stroke, a leading cause of disability. Yet, their effectiveness varies because BCI typically need to be customized for each patient. Our innovative methodology focuses on the brain-heart interplay and combines network science and biomedical signal processing to estimate interactions between these two systems in the context of motor imagery. We will explore various approaches, such as generative data methods, multi-layer networks, higher-order dependencies, and deducing potential causal interactions from physiologically informed neural models. Our ultimate goal is to pave the way for future biomedical breakthroughs in the emerging field of brain-heart interplay. Through these efforts, NETCORE strives to enhance the potential of BCI in aiding brain-injured patients and showing the potential of studying brain-heart interplay in healthcare and neuroscientific research.

9.3.2 H2020 projects

ERC BCINET

Participants: Fabrizio De Vico Fallani *(Correspondant)*.

Project title: Non-invasive decoding of brain communication patterns to ease motor restoration after stroke

Duration: 2020-2027

Amount: 2M€

Coordinator: Fabrizio, De Vico Fallani

Otherpartners: ICM

Summary: Brain–computer interfaces (BCIs) can bypass the skeletomuscular system, assisting paralysed people in control and communication. However, despite their application in neuromotor rehabilitation, the accuracy of sensory feedback is still highly variable, limiting their use in everyday life. Scientists of the EU-funded BCINET project propose to address this issue through a novel generation of BCIs that do not solely rely on data from selected brain regions but integrate the user's brain network information. Using a combination of neuroimaging and experimental methods within a modern computational framework, they will study brain dynamics to improve BCI architecture and accuracy. Apart from refining BCIs, the project has the potential to unveil solutions for motor restoration after stroke.

9.4 National initiatives

ANR-PRC BETPARK

Participants: Mario Chavez, Fabrizio De Vico Fallani *(Correspondant)*.

Project title: Neurofeedback for Parkinson's disease

Duration: 2021 - 2025

Amount: 712k€

Coordinator: Nathalie George

Other partners: CNRS CCLE; ICM

Summary: Parkinson's disease (PD) is a complex neurodegenerative disease caused by death of midbrain dopaminergic neurons. This calls for better understanding the pathophysiology of PD in order to pave the way to new non-pharmacological and non-invasive treatment options for PD. We propose to use neurofeedback (NF) to test whether PD patients can learn to self-regulate their brain activity to reduce

pathological neural activity and thereby motor symptoms. We will leverage NF to target regulation of pathological beta band (8-35 Hz) oscillations, and we will characterize training-induced changes in cortical network activity and their relationship with symptom severity. Our goal is to provide direct evidence of the functional role of beta rhythms in the pathophysiology of PD while assessing NF as a new non-pharmacological and non-invasive tool for ameliorating PD motor symptoms.

ANR-PRC MEO

Participants: Laurent Hugueville *(Correspondant)*.

Project title: Overcome SQUID and alkali OPM limitations for Epilepsy: 4He OPMs

Duration: 2022 - 2025

Amount: 639k€

Coordinator: Francesca Bonini

Other partners: MAG4Health,CRNL,INS,APHM, ICM

Summary: The main objective of this highly interdisciplinary and collaborative project is to demonstrate that innovative optically pumped magnetometers (OPM) using helium-4 (4HeOPM) can overcome the limitations of SQUID and alkali OPM sensors to monitor brain activity in epileptic patients including children and to perform long-term recording of epileptic seizures. Innovative optically pumped magnetometers (OPMs) using helium-4 (4HeOPM) have been developed by Mag4Health, which operate at room temperature. These sensors can be placed near the scalp and have a wider dynamic range and bandwidth more suitable for detecting epileptic activities. Our aim is to demonstrate their capability to overcome the limitations of commercially available MEG systems (sMEGs) as well as prototype alkaline OPM, thus opening new horizons for the non-invasive pre-surgical evaluation of epilepsy including recording of seizure onset.

MinArm-Inria Boucle Dort

Participants: Mario Chavez *(Correspondant)*.

Project title: Neurofeedback for Parkinson's disease

Duration: 2025 - 2027

Amount: 312k€

Coordinator: Mario Chavez

Other partners: Inria, SSA

Summary: Severe hemorrhage remains the leading cause of death among wounded military personnel. The objective of the Boucle DORT project is to continue the development of an embedded automated system for the management of critically injured patients and to extend its application beyond hemorrhagic trauma alone. The envisioned uses of the system range from automated resuscitation to the comprehensive management of severe trauma, including hemorrhagic shock, traumatic brain injury, and severe burns. The current project focuses on the development of algorithms and a software interface for to the development of a prototype dedicated interface, together with a software application enabling patient categorization, integration with physiological monitoring systems, and control of an automated device capable of administering selected treatments in closed loop (catecholamines, fluid resuscitation, and sedation).

9.4.1 ANR

Grasp-IT, ANR PRCE CES 33 (interaction, robotics)

Title: Design and evaluation of a tangible and haptic brain-computer interface for upper limb rehabilitation after stroke

Duration: Jan2020-July2024

Coordinator: Laurent Bougrain (LORIA/NeuroRhythms)

Partners:
- LORIA (Lorraine Research Laboratory in Computer Science and its Applications)
- Center for research Inria Rennes - Bretagne Atlantique
- Center for research Inria Sophia Antipolis - Méditerranée
- IRR UGECAM-NE centre Lay Saint Christophe
- CHU Rennes / Physical Medicine and Rehabilitation Service
- CHU Toulouse
- SARL ALCHIMIES

Loria contact: Laurent Bougrain

Summary: This project aims to recover upper limb control improving the kinesthetic motor imagery (KMI) generation of post-stroke patients using a tangible and haptic interface within a gamified Brain-Computer Interface (BCI) training environment. (i) This innovative KMI-based BCI will integrate complementary modalities of interactions such as tangible and haptic interactions in a 3D printable flexible orthosis. We propose to design and test usability (including efficacy towards the stimulation of the motor cortex) and acceptability of this multimodal BCI. (ii) The GRASP-IT project proposes to design and integrate a gamified non-immersive virtual environment to inter- act with. This multimodal solution should provide a more meaningful, engaging and compelling stroke rehabilitation training program based on KMI production. (iii) In the end, the project will integrate and evaluate neurofeedbacks, within the gamified multimodal BCI in an ambitious clin- ical evaluation with 75 hemiplegic patients in 3 different rehabilitation centers in France. The GRASP-IT project represents a challenge for the industrial 3D printing field. The materials of the 3D printable orthosis, allowing the integration of haptic-tangible interfaces, will come from a joint R&D work performed by the companies Alchimies and Open Edge.

BCI4IA, ANR PRC CES 19 (Technologies for health)

Title: a New BCI Paradigm To Detect Intraoperative Awareness During General Anesthesia

Duration: Jan2023-Dec2026

Coordinator: Claude Meistelman (CHRU Nancy)

Partners:
- CIC regional university hospital of Nancy
- LORIA
- Center for research Inria Bordeaux - Sud-Ouest
- Anesthesia and intensive care unit/CHU-Brugmann, Belgium (unfunded)
- Laboratory of Neurophysiology and Movement Biomechanics/Université Libre de Bruxelles, Belgium (unfunded)

Loria contact: Laurent Bougrain

Summary: The BCI4IA project aims to design a brain-computer interface to enable reliable general anesthesia (GA) monitoring, in particular to detect intraoperative awareness. Currently, there is no satisfactory solution to do so whereas it causes severe post-traumatic stress disorder. "I couldn't breathe, I couldn't move or open my eyes, or even tell the doctors I wasn't asleep." This testimony shows that a patient's first reaction during an intraoperative awareness is usually to move to alert the medical staff. Unfortunately, during most surgery, the patient is curarized, which causes neuromuscular block and prevents any movement. To prevent intraoperative awareness, we propose to study motor brain activity under GA using electroencephalography (EEG) to detect markers of motor intention (MI) combined with general brain markers of consciousness. We will analyze a combination of MI markers (relative powers, connectivity) under the propofol anesthetics, with a brain-computer interface based on median nerve stimulation to amplify them. Doing so will also require to design new machine learning algorithms based on one-class (rest class) EEG classification, since no EEG examples of the patient's MI under GA are available to calibrate the BCI. Our preliminary results are very promising to bring an original solution to this problem which causes serious traumas.

ANR-JCJC MANET

Participants: Marie-Constance Corsi *(Correspondant)*.

Project title: Multimodal Approaches based on Neurophysiological markers to Enhance brain-computer inTerfaces (MANET)

Duration: 2026 - 2029

Amount: 285k€

Coordinator: Marie-Constance Corsi

Summary: Despite being beneficial for patients, controlling a BCI system is a learned skill that a non-negligible proportion of the users cannot develop even after training sessions. This phenomenon, called "BCI inefficiency" constitutes a strong limitation to the BCI diffusion. The "BCI inefficiency" concept is useful to understand why some users cannot interact well with BCI technologies. Nevertheless, it relies on the assumption that users are expected to reach an accuracy level within a finite time; and it infers that it is inherently on the user. Therefore, instead of considering the user as a cause of the observed variability, it appears essential to develop BCI systems that aim at considering the user's specificity. The underlying challenge here is to extract the most relevant information to discriminate properly the user's mental state, referred as "features". My goal is to develop methods to assess and to improve BCI performance by considering the subjects' specificity. Aware that the BCI training relies on mutual-learning schemes between the users and the machines, I will propose a framework that tackles the "BCI inefficiency" phenomenon from both the neural decoder and the users' sides. I first propose to enrich the decoded features by considering combination of multimodal and heterogeneous information to develop innovative classification tools (WP1). Then, I will generalize this framework by introducing new features based on the identification of reliable and subject-specific neurophysiological markers of BCI performance (WP 2). Finally, I will conduct an experimental validation through online BCI experiments based on new generation of MEG sensors, namely the optically-pumped magnetometers (OPMs) (WP 3).

AI Cluster PrAIrie-PSAI

Participants: Fabrizio De Vico Fallani *(Correspondant)*.

Project title: Hihger-order interactions in brain networks

Duration: Since 2024

Amount: 75M€

Coordinator: Isabelle Ryl

Other partners: PSL,CNRS,Paris Cite, Inria, Pasteur

Summary: As AI confirms its role as a disruptive technology and its impact on all sectors of society, the PRAIRIE - Paris School of AI project is positioned as a catalyst for innovation and research in AI, with the ambition of becoming the world leader that France needs to remain competitive on the international stage. Winner of the IA Cluster call for 75 million, it brings together the same players who, since 2019, have made the 3IA PRAIRIE Institute a success and established it on the world stage as a leading player in Artificial Intelligence (AI) research and training. Taking full advantage of this momentum, PRAIRIE-PSAI will broaden the positioning of the 3IA PRAIRIE Institute, by federating the interdisciplinary research and training initiatives of its partners. The strength of the consortium is unique in this respect.

10 Dissemination

10.1 Promoting scientific activities

10.1.1 Scientific events: organisation

General chair, scientific chair

- Marie-Constance Corsi co-chaired the "Next Generation Brain-Computer Interface" workshop during the IEEE MetroXRAINE conference in October 2025 (Ancona, Italy)
- Marie-Constance Corsi co-chaired the "Brain models as a tool for a multimodal integration" symposium during the 1st OHBM Satellite Meeting in September 2025 (Virtual)
- Marie-Constance Corsi co-chaired the Special Session on "Decoding the brain time series" during the 35th IEEE International Workshop on Machine Learning for Signal Processing (IEEE MLSP 2025) in August 2025 (Istanbul, Turkey)
- Marie-Constance Corsi co-chaired with Tristan Venot the "Exploring features to improve BCI: challenges and opportunities" workshop during the 11th BCI meeting in June 2025 (Banff, Canada)
- Laurent Bougrain co-chaired the "Exploring Altered States of Consciousness Through EEG and BCI" workshop at the 47th IEEE IEEE Engineering in Medicine and Biology Society (EMBC 2025) in July 2025 (Copenhaguen, Denmark)
- Laurent Bougrain co-chaired the "Exploring the Clinical Integration of BCI Technology in General Anesthesia Monitoring" workshop at the BCI Meeting in June 2025 (Banh, Canada)

Member of the organizing committees

- Fabrizio De Vico Fallani co-organized Network Neuroscience 2025 at NetSci Maastricht, Neitherlands
- Marie-Constance Corsi co-organized PracticalMEEG 2025 (sponsored by Inria) in October 2025 (Aix-en-Provence, France)
- Marie-Constance Corsi co-organized with C. Cury and P. Maurel (EPI Empenn) the "Journées Scientifiques Inria" in June 2025 (Paris, France)

Data competition

- "EEG Foundation Challenge: From Cross-Task to Cross-Subject EEG Decoding" (EEG Challenge 2025) - Submision accepted to the NeurIPS 2025 Competition Track. This competition was led by Bruno Aristimunha Pinto together with the other core coordinators. Marie-Constance Corsi was part of the Domain experts. There were 1,183 teams/participants and more than 8,000 submissions on the open source platform Codabench. A record for the EEG domain!

10.1.2 Scientific events: selection

Member of the conference program committees

- Fabrizio De Vico Fallani was member of the Complex Systems Society conference 2025
- Fabrizio De Vico Fallani served as member for NetSciX 2025
- Fabrizio De Vico Fallani served as member of Complex Networks 2025
- Fabrizio De Vico Fallani served as member for Complenet 2025

Reviewer

- Fabrizio De Vico Fallani served as reviewer for NetSci 2025
- Fabrizio De Vico Fallani served as reviewer for NetSciX 2025
- Fabrizio De Vico Fallani served as reviewer for Complex Networks 2025
- Fabrizio De Vico Fallani served as reviewer for Complenet 2025
- Marie-Constance Corsi served as reviewer for NeurIPS 2025
- Marie-Constance Corsi served as reviewer for IEEE MetroXRAINE 2025
- Marie-Constance Corsi and Laurent Bougrain served as reviewer for CORTICO 2025

10.1.3 Journal

Member of the editorial boards

- Fabrizio De Vico Fallani served as Academic Editor for Brain Topography
- Marie-Constance Corsi served as Academic Editor for PLOS ONE
- Diego Candia-Rivera served as Academic Editor for The Journal of Physiology

Reviewer - reviewing activities

- Fabrizio De Vico Fallani served as reviewer for Nature Communications, Network Neuroscience, Journal of Neural Engineering
- Marie-Constance Corsi served as reviewer for eNeuro, NeuroImage: Clinical, Brain Topography, Brain Connectivity, Journal of Neural Engineering, IEEE Transactions on Biomedical Engineering (TBME), IEEE Reviews in Biomedical Engineering, Scientific Reports, PLOS ONE, Brain-Computer Interfaces, Epilepsy Open
- Mario Chavez served as reviewer for Physical Reviw E, Brain Cmmunications, Proceeedings of the National Academy of Sciences Nexus, Chaos, NPJ Digital Medecine
- Laurent Bougrain served as reviewer for Brain Topography, Virtual Reality'25, Cortico'25

- Diego Candia-Rivera served as reviewer for Computers in Biology and Medicine, Clinical Neurophysiology, Experimental Physiology, Biological Psychiatry, Annals of the New York Academy of Sciences, Communications Biology, Nature Reviews Neurology, Social Cognitive and Affective Neuroscience, Physiological Measurement, Nature Human Behaviour, Progress in Neurobiology, Springer Books
- Andrea Civilini served as reviewer for Communications Physics, Chaos Solitons and Fractals, Journal of Complex Networks

10.1.4 Invited talks

- Fabrizio De Vico Fallani gave an invited talk at the Bernstein network computational neuroscience conference, Frankfurt 2025
- Fabrizio De Vico Fallani gave an invited talk at the 11th Brain-computer interface meeting, Banff Canada, 2025
- Fabrizio De Vico Fallani gave an invited talk Inria-Brasil Workshop on digital health, Hybrid 2025
- Fabrizio De Vico Fallani gave an invited talk NETSCI Workshop on networks in biology and medicine, Maastricht 2025
- Marie-Constance Corsi gave a plenary talk during the 11th BCI meeting (Early Career Award) in June 2025 (Banff, Canada)
- Marie-Constance Corsi gave a talk during the AI-Data workshop of the 11th BCI meeting in June 2025 (Banff, Canada)
- Marie-Constance Corsi presented her work during the France-Taiwan STC workshop (AI & Health) in October 2025 (Paris, France)
- Marie-Constance Corsi presented her work during an Essex BCI-NE webinar in December 2025
- Marie-Constance Corsi presented her work during a seminar organized by the Institut de Neuromodulation in November 2025 (Paris, France)
- Marie-Constance Corsi presented her work during a seminar organized by the "Ingénierie Cognitive et Neurosciences appliquées" (ICNA) department of the ONERA in August 2025 (Salon de Provence, France)
- Marie-Constance Corsi was invited to present during the NxGenBCI workshop during the last IEEE MetroXRAINE in October 2025 (Ancona, Italy)
- Mario Chavez was invited to give the talk “The intrinsic geometry of complex brain networks as biomarkers in epilepsy”, within the School on Synchronization : from colective motion to brain dynamics, held at the ICTP-Sao Paulo, Brazil, in February 2025
- Mario Chavez was invited to give the talk “The intrinsic geometry of complex brain networks as biomarkers in epilepsy”, at the UBICS, University of Barcelona, in Mars 2025
- Mario Chavez was invited to give the talk “Brain Connectivity and Cinical Monitoring”, at the Taller de Sistemas Complejos, Universidad Autonoma del Estado de Morelos, Cuernavaca, Mexico, in May 2025
- Mario Chavez was invited to give the talk “The intrinsic geometry of complex brain networks as biomarkers in epilepsy”, at the Conference LANET, Punta del Este, Uruguay, in July 2025
- Mario Chavez was invited to give the talk “Hyperbolic embedding of brain networks for detecting regions disrupted by neurodegeneration”, at the seminar “Redes complejas, Estructura Procesos Dinamicos”, at the Universidad de Buenos Aires, Argentina, in July 2025

- Laurent Bougrain was invited to present his work during two talks on "Artificial Intelligence for EEG-based Brain-Computer Interfaces" and "Designing non-invasive brain-computer interfaces" at the engineering of the national university of Entre Rios(Parana, Argentina)
- Laurent Bougrain was invited to present his work on "Designing a non-invasive BCI for upperlimb rehabilitation after stroke" Bordeaux university on September 29, 2025, Bordeaux, France
- Diego Candia-Rivera was invited to present at the University of Glasgow, December 2025 (Glasgow, UK)
- Diego Candia-Rivera was invited to present during the International Union of Physiological Societies World Congress 2025 (Frankfurt, Germany)
- Diego Candia-Rivera was invited to present during the Paris Postdoc Seminars. January 2025 (Paris, France)

10.1.5 Leadership within the scientific community

- Marie-Constance Corsi is member of the scientific advisory board of CuttingEEG
- Laurent Bougrain & Marie-Constance Corsi are members of the Board of Directors of the scientific society CORTICO for the promotion of Brain-Computer Interfaces in France.

10.1.6 Scientific expertise

- Marie-Constance Corsi served in 2025 as reviewer for the call for proposal entitled "Data IA Insitute: AI Modular Chairs"
- Marie-Constance Corsi served in 2025 as reviewer for the call launched by the Dutch Research Council Domain Applied and Engineering Sciences (NWO Domain AES)
- Marie-Constance Corsi served in 2025 as reviewer for the call launched by Toulouse Initiative for Research Impact on Society (TIRIS)
- Marie-Constance Corsi has served since 2025 as reviewer for the Paris Brain Institute call for Carnot Tools/Maturation projects
- Mario Chavez served in 2025 as reviewer for the call ERC Consolidator Grant
- Mario Chavez served in 2025 as reviewer for the French call (“bourses”) of the Ligue Française contre l’Epilepsie
- Diego Candia-Rivera served in 2025 as reviewer for the AAPG Generic call – Agence Nationale de la Recherche (ANR)

10.1.7 Research administration

- Fabrizio De Vico Fallani has served in the 2025 Inria Groupe de travail - Creation EPC COPHY
- Fabrizio De Vico Fallani has served as ICM representative for the European Brain Research Infrastructures - Ebrains
- Marie-Constance Corsi has served as member of the Inria Paris Doctoral Advisory Committee since 2025
- Marie-Constance Corsi has served as member of the Inria Paris Center Committee since 2025

10.2 Teaching - Supervision - Juries - Educational and pedagogical outreach

10.2.1 Teaching

- Fabrizio De Vico Fallani, MAPIMED course, Sorbonne Univ., Complex brain networks (3h), Paris, France
- Marie-Constance Corsi, CENIR course, ICM, Brain-Computer Interface (2h), Paris, France
- Marie-Constance Corsi, DU IA Santé, Univ. Paris Cité, Introduction to Brain-Computer Interfaces (1h), Paris, France
- Marie-Constance Corsi, Master Computational Neuroscience and Neuroengineering (CNN), Univ. Paris-Saclay, Network science for understanding Brain-Computer Interfaces (3h), Saclay, France
- Marie-Constance Corsi, Master Mathématiques Vision Apprentissage (MVA), ENS Saclay, Imagerie fonctionnelle cérébrale et interface cerveau machine (9h), Saclay, France
- Laurent Bougrain, "Brain-computer Interfaces" and "Signal processing and machine learning of electroencephalographic Signals" (8h), Licence and Master in Life Science and Systems Engineering, Kyushu Institute of Technology (Kyutech), Kitakyushu-shi, Fukuoka, Japan

10.2.2 Supervision

- PhD Theses
  - Camilla Mannino: co-supervised by Mario Chavez & Marie-Constance Corsi
  - Martin Guillemaud: supervised by Mario Chavez
  - Alice Longhena: supervised by Mario Chavez
  - Cassandra Dumas: co-supervised by Nathalie George (CNRS, ICM) & Marie-Constance Corsi
  - Marc Fiammante: supervised by Mario Chavez
  - Sébastien Velut: co-supervised with Frédéric Dehais (ISAE-Supaero), Sylvain Chevallier (Univ. Paris-Saclay, EPI TAU) & Marie-Constance Corsi
  - Jules Gomel: co-supervised by Frédéric Dehais (ISAE-Supaero) & Marie-Constance Corsi
  - Bruno Aristimunha Pinto: co-supervised by Sylvain Chevallier (Univ. Paris-Saclay, EPI TAU), Raphael Camargo (Universidade Federal do ABC, Brazil) & Marie-Constance Corsi
  - Baptiste Fague: co-supervised by Elisa Tartaglia (EssilorLuxottica) & Marie-Constance Corsi
  - Giovanni Messuti: co-supervised by Silvia Scarpetta (Univ of Salerno, Italy) & Marie-Constance Corsi
- Master Theses
  - Pierre-Baptiste Mathieu de Carvalho: co-supervised by Laurent Bougrain & Marie-Constance Corsi co-supervised (April-Sept 2025)
  - Mario Roca: supervised by Marie-Constance Corsi (Feb-August 2025)
  - Francesco Farina: supervised by Mario Chavez (Feb-July 2025)
  - Laura Pitti: supervised by Diego Candia-Rivera (September 2025-February 2026)
  - Giovanni Sitti: supervised by Diego Candia-Rivera (September 2025-February 2026)
  - Linon Denis: supervised by Mario Chavez (October 2025-April 2026)
- Bachelor's thesis internship
  - Apurba Debnath: co-supervised by Parul Verma (IIT Madras, India) and Marie-Constance Corsi (Jan-July 2025)

10.2.3 Juries

- Fabrizio De Vico Fallani, President, PhD committee of D Trocellier, PhD Informatics, Univ Bordeaux
- Fabrizio De Vico Fallani, Relator, PhD commitee of D Hajhassani, PhD Biomedical engineering, Univ Grenoble-Alpes
- Marie-Constance Corsi, admissibility jury member, CRCN Inria Bordeaux
- Marie-Constance Corsi, Examiner, PhD committee of Ambroise Heurtebise (Paris-Saclay University), Saclay, France
- Marie-Constance Corsi, Examiner, PhD committee of Hasnae Agouram (Aix-Marseille University), Marseille, France
- Marie-Constance Corsi, Examiner, PhD committee of Edouard Ferrand (Paris-Saclay University), Saclay, France
- Marie-Constance Corsi, Examiner, PhD committee of Alix Lamouroux (Ecole nationale supérieure Mines-Télécom Atlantique), Brest, France
- Marie-Constance Corsi, Examiner, PhD committee of Hanane Moumane (Sorbonne University), Paris, France
- Marie-Constance Corsi, Examiner, PhD committee of Zaineb Ajra (Montpellier University), Montpellier, France
- Mario Chavez, Examiner, PhD committee of Hamed Azizollahi (Université de Picardie Jules Verne), Amiens, France, July 2025
- Mario Chavez, Examiner, PhD committee of Claudio Caprioli (University of Catania), Italy, September 2025
- Mario Chavez, Examiner, Professorship Promotion Committee of Nasrine Jrad (Université Catolique de l'Ouest), Angers, France, June 2025
- Laurent Bougrain, Examiner, PhD committee of David Trocelier Bordeaux university on September 29, 2025, Bordeaux, France
- Laurent Bougrain, Opponent, PhD committee of Pex Pufvesson Lund university on November 21, 2025, Lund, Sweeden
- Diego Candia-Rivera, Examiner, PhD committee of Lauren Zwienenberg (Maastricht University), Maastricht, The Netherlands

10.2.4 Educational and pedagogical outreach

- Celestine AllombertBlaise welcomed five schoolchildren (during a "stage de 3e" internship week) in the NERV Team at the Paris Brain Institute (ICM). The aim of this initiative was to introduce them to neuroscience research through interactive presentations, lab visits, and hands-on demonstrations together with team members.

10.3 Popularization

10.3.1 Specific official responsibilities in science outreach structures

- Marie-Constance Corsi: member of the organizing committee of the France Brain Bee (Olympiades de Neurosciences)

10.3.2 Participation in Live events

- Fabrizio De Vico Fallani organized and moderated the roundtable on Network Neuuroscience as part of the NSF-supported Accelenet-Multinet international program.
- Fabrizio De Vico Fallani participated as a panelist in a round table on BCIs organized by DIM C-BRAINS at the Centre International de Conferences of Sorbonne University.

10.3.3 Others science outreach relevant activities

- Fabrizio De Vico Fallani, talk given during "Les Matinales de l'Institut du Cerveau" event at Paris Brain Institute
- Marie-Constance Corsi, participation to the "Becoming a PI" wokshop organized at the Paris Brain Institute
- Marie-Constance Corsi, presentation to the "Institut de la gestion publique et du développement économique" (IGPDE)
- Marie-Constance Corsi, presentation to the SCAI Spring School on "How can emotionally intelligent AI transform society"
- Marie-Constance Corsi, talk given during the "Les Mardis de la Sorbonne" event
- Mario Chavez and Marc Fiammante , presentation of the project "NewBorn NeuroDigital" to the French President M Emmanuel on the occasion of the Summit for Action on Artificial Intelligence (AI), which took place on 10 and 11 February 2025 in Paris, France
- Laurent Bougrain Oxford-Style Debate : "Connaître le cerveau est nécessaire pour le développement à venir de l'IA", affirmative team , Forum des Sciences Cognitives et du TAL, Nov. 26, 2025, Théâtre de la Manufacture, Nancy.
- Celestine AllombertBlaise and Bintou Soumaoro have regularly contributed to the team's online communication by updating the official website as well as the LinkedIn and Bluesky accounts. They have published outreach posts highlighting recent scientific articles, team news, and public engagement initiatives.

11 Scientific production

11.1 Major publications

[1] R. Ben Messaoud, V. L. Du, C. Bousfiha, M.-C. Corsi, J. Gonzalez-Astudillo, B. C. Kaufmann, T. Venot, B. Couvy-Duchesne, L. Migliaccio, C. Rosso, P. Bartolomeo, M. Chavez and F. de Vico Fallani. 'Low-dimensional controllability of brain networks'. In: *PLoS Computational Biology* (2025). URL: https://hal.science/hal-04302540.

[2] D. Candia-rivera, L. Faes, F. d. V. Fallani and M. Chavez. 'Measures and Models of Brain-Heart Interactions'. In: *IEEE Reviews in Biomedical Engineering* (2025), pp. 1–17. DOI: 10.1109/RBME.2025.3529363. URL: https://hal.science/hal-04881986. In press.

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[4] A. Longhena, M. Guillemaud, F. d. V. Fallani, R. Migliaccio and M. Chavez. 'Hyperbolic embedding of brain networks detects regions disrupted by neurodegeneration in Alzheimer's disease'. In: *Physical Review E* (Apr. 2025). DOI: 10.1103/PhysRevE.111.044402. URL: https://hal.science/hal-04884605.

11.2 Publications of the year

International journals

[5] R. Ben Messaoud, V. L. Du, C. Bousfiha, M.-C. Corsi, J. Gonzalez-Astudillo, B. C. Kaufmann, T. Venot, B. Couvy-Duchesne, L. Migliaccio, C. Rosso, P. Bartolomeo, M. Chavez and F. de Vico Fallani. 'Low-dimensional controllability of brain networks'. In: *PLoS Computational Biology* (2025). URL: https://hal.science/hal-04302540 (cit. on p. 13).

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[7] Q. Calonge, A. Hanin, E. Januel, O. Guinebretiere, T. Nedelec, F. Le Gac, M. Chavez, S. Tezenas Du Montcel and V. Navarro. 'Incidence, mortality, and management of status epilepticus from 2012 to 2022: An 11-year nationwide study'. In: *Epilepsia* (3rd Sept. 2025). DOI: 10.1111/epi.18627. URL: https://hal.sorbonne-universite.fr/hal-05276617.

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[27] V. M. Cueva, F. Lotte, L. Bougrain and S. Rimbert. 'From Post-Median Nerve Stimulation ERD to MI-BCI Expertise Prediction'. In: BCI 2025 - 13th International Winter Conference on Brain-Computer Interface. Seoul, South Korea: IEEE, 24th Feb. 2025, pp. 1–6. DOI: 10.1109/BCI65088.2025.10931645. URL: https://inria.hal.science/hal-04981146 (cit. on p. 15).

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[31] T. de Surrel, T. Venot, M.-C. Corsi and F. Yger. 'Interpretability of Riemannian tools used in brain computer interfaces'. In: MLSP 2025 - 35th IEEE International Workshop on Machine Learning for Signal Processing. Istanbul, Turkey: IEEE, 31st Aug. 2025, pp. 1–6. DOI: 10.1109/MLSP62443.2025.11204309. URL: https://hal.science/hal-05245110 (cit. on p. 13).

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[32] C. Dumas, C. Dussard, N. George and M.-C. Corsi. 'Characterization and Usability of Common Spatial Pattern Features in Motor Imagery Neurofeedback'. In: SPNC 2025 - Journées "Brain Insights into Memory and Consciousness" de la Société de Psychophysiologie et de Neurosciences Cognitives. Paris, France, 6th Nov. 2025. URL: https://hal.science/hal-05366284.

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Doctoral dissertations and habilitation theses

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