Département
D5: Complex Systems, Artificial Intelligence and Robotics

Équipe NeuroRhythms

Computational Modeling and Experimental Analysis of Normal and Pathological Neural Rhythms for Medical Applications and Social Robotics

Loria

Laboratoire lorrain de recherche en informatique et ses applications

Rapport d'activité 2025

cnrs UNIVERSITÉ DE LORRAINE

En partenariat avec

Inria CentraleSupélec

Contents

Team NeuroRhythms

Keywords

Computational neuroscience, biological neural networks, synchronization, brain signal analysis, sensory-motor loop, retina, memory, anesthesia, neurofeedback, brain-machine interfaces, neurorobotics, humanoid robots, mobile robots, neuro-rehabilitation, motor-coordination, human-robot interactions.

1 Team members, visitors, external collaborators

Faculty Members

- Laurent Bougrain [UL, Associate Professor, Team leader, delegated at Inria Paris in Nerv project-team at the Paris Brain Institute]
- Laure Buhry [UL, Associate Professor, HDR, until oct. 2025]
- Hendry Ferreira Chame [UL, Associate Professor, until June. 22, 2025]

PhD Students

- Laëtitia Raison Aubry [UL, PhD Student]
- Lénaïg Guého [Orange Innovation, PhD Student]
- Faustine Faccin [Noviga, PhD Student]
- Sarah Hamdi Cherif [UL, PhD Student]
- Valérie Marissens Cueva [Inria Bordeaux, PhD Student]

Technical Staff

- Jérémy Frey [UL, Engineer, from Feb. 24 until July 14, 2025]
- Pierre-Baptiste Mathieu de Carvahlo [UL, Temporary technical assistant, from Oct. 6 until Dec. 5, 2025]

Interns and Apprentices

- Pierre-Baptiste Mathieu de Carvahlo [UL, from April until August 2025]
- Fikreselassie Eshetu Seid [UL, from April until July 2025]
- Aymane Benamar [UL, from April until June 2025]
- Achille Richard-Calvo [UL, from April until June 2025]

Visitors

- Hiroaki Wagatsuma [Kyutech univ., Professor, from Sept. 10 until Oct. 12, 2025]
- Rena Kato [Kyutech univ., Master student, from Sept. 10 until Oct. 12, 2025]
- Kosei Shibata [Kyutech univ., Intern, since Sep. 10, 2025]

Administrative Assistant

- Antoinette Courrier [UL]

External Collaborators

- Radu Ranta [PR, CRAN-UL]
- Jérémie Gaidamour [IR CNRS, IECL]

2 Overall objectives

Neural rhythms can be found throughout the central nervous system e.g., between brain areas as well as in the spinal cord. As a consequence, rhythms are known to be involved in numerous brain functions such as perception (e.g. vision) and motor coordination (including inter-limb and inter-personal movement coordination), cognition (states of awakeness, memory consolidation...) and emotions [0]. Excess or deficit in oscillation or synchrony may further relate to neurological disorders. Thus, studying normal and pathological rhythmic activity is essential to better understand Parkinson's disease, tremor, epilepsy, or psychiatric diseases and propose neural interfaces for regulating the nervous system or enhancing functional recovery [0, 0]. Also, studying rhythms unfolding in human-robot interaction is a promising way to understand high level social cognitive processes in the human and at the same time to develop bio-inspired models of robot behavior suitable for humans.

3 Research program

Studying neural rhythms requires i) building realistic models ii) validated by experimental data recorded in humans and animals or by interactions with the real world including humans or robots.

3.1 Computational modeling of neural rhythms

NeuroRhythms works at complementary levels of modeling of oscillatory neural activity [0, 0, 0]: the microscopic scale that reproduces the spiking activity using detailed synapse and Hodgkin-Huxley neuron models [0], and the mesoscopic scale that reproduces the functionality of a population of neurons using non-linear oscillators like Van der Pol models [0, 0], Rayleigh [0] or Hopf models [0, 0]. A third level of modeling (macroscopic scale) is used to investigate high level cognitive functions such as attention, spatial representation and memory, based on dynamic neural fields theory [0]. All our models are based on coupled nonlinear ordinary differential equations. The choice of detailed (microscopic) versus functional (mesoscopic or macroscopic) level depends on the size of the population of neurons to be modeled, on the resultant computational complexity and on the prior knowledge and experimental data available to estimate the model parameters. Combining these scales is beneficial when modeling brain structures that consists of several neural populations with different sizes and levels of details [0]. Some important goals of our team are to develop a composite model of a part of the motor system for studying Parkinson's disease including subnetworks of the basal ganglia, the cerebral cortex and the spinal cord; and to investigate social cognition though human-robot interaction modeling.

The computer science tools and methods concern (i) stochastic optimization algorithms for exploring large parameter spaces to fit neural models to real data [0, 0, 0] and (ii) event-driven and voltage-stepping integration strategies for parallel simulations of large-scale networks [0] on GRID5000.

3.2 Confronting models and experimental data

In addition to a theoretical analysis of the dynamic behavior of models, experimental analysis of rhythmic activity is necessary to understand oscillatory dynamics and to design the corresponding computational models. Experimental data are obtained from our ongoing collaborations with electrophysiologists and medical doctors or by carry on experiments on real robots.

Nervous systems in animals and humans exhibit cognitive sophistication for controlling dynamic movements in locomotion and navigation that needs to be modelled, simulated and confronted to real physical environment to be well understood, improved and validated. Neurorobotics is an emerging

science that studies perception-action loops using neural models embodied in robots like flying autonomous robot or humanoids. Observing how the robot interacts with its environment (including humans) allows to study how sensory and motor systems have to cooperate to produce the appropriate motor response to a given stimulus. This understanding can further serve as a source of inspiration for future controller architectures in robotics.

4 Application domains

Our research directions are motivated by applications with a high impact on healthcare, education or social. They are developed in collaboration with medical partners, neuroscientists, and psychologists. Several of our applications can be seen as neural interfaces which require analysis and modeling of neuronal of cardiac rhythms (recovery after stroke, detection of peroperative awareness during general anesthesia, detection of sleep apnea syndrome, modeling of pathophysiological mechanisms of schizophrenia). Other applications include models of human-robot interaction based on social cognition skills.

5 Social and environmental responsibility

Our experiments in humans are subject to approval by ethics committees (*Comité de Protection des Personnes*, Operational Committee for the assessment of Legal and Ethical risks at Inria,...). We also organized a conference including a round-table discussion about ethics in neurotechnology at Cortico'24.

Simulating detailed models with a large number of neurons in computational neuroscience requires a significant computing power, as does machine learning on large databases. We pay particular attention to the implementation of our models, to make them faster and more compact.

Our modeling and simulation works of (patho)physiological mechanisms play an increasing role since the introduction or the 3R-rule by the European Commission aiming at limitating the use of animal experiment.

We have been interested in the representation of women in science for many years. Currently, in December 2023, the team has 2 men and 1 woman as permanent staff and 6 female PhD students.

6 Highlights of the year

- L. Bougrain is delegated in the Inria project-team Nerv at the Paris Brain Institute (CNRS/INSERM/AP-HP/Sorbonne univ.).
- L. Buhry was on partial training leave (medical training).
- L. Buhry received a PIQ grant (Programme Inria Quadrant), a program supporting High-Risk High-Reward Research in digital science and technology. Project applied to psychiatry, to be started in 2026.

7 New software, platforms, open data

7.1 New software

OpenVIBE

Title: Software for Brain-Computer Interfaces and realtime neuroscience

Keywords: Neurosciences, Interaction, Virtual reality, Health, Realtime, Neurofeedback, Brain-Computer Interface, EEG, 3D interaction

Coordinator: Anatole Lécuyer,

Authors: Charles Garraud , Jérôme Chabrol, Thierry Gaugry, Cedric Riou, Yann Renard, Anatole Lécuyer, Jozef Legény, Laurent Bonnet, Jussi Tapio Lindgren, Fabien Lotte, Thomas Prampart, Thibaut Monseigne

Participants: Cedric Riou, Thierry Gaugry, AnatoleLécuyer, Thomas Prampart,FabienLotte, Laurent Bougrain, Maureen Clerc, Théodore Papadopoulo Partners: INSERM,GIPSA-Lab

Loria contact: Laurent Bougrain

Summary: OpenViBE is a free and open source software platform devoted to the design, test and use of Brain-Computer Interfaces (BCI). The platform consists of a set of software modules that can be integrated easily and efficiently to design BCI applications. The key features of OpenViBE software are its modularity, its high-performance, its portability, its multiple-users facilities and its connection with high-end/VR displays. The designer of the platform enables to build complete scenarios based on existing software modules using a dedicated graphical language and a simple Graphical User Interface (GUI). This software is available on the Inria Forge under the terms of the AGPL licence, and it was officially released in June 2009. Since then, the OpenViBE software has already been downloaded more than 60000 times, and it is used by numerous laboratories, projects, or individuals worldwide. More information, downloads, tutorials, videos, documentations are available on the OpenViBE website.

Projetc website: https://openvibe.inria.fr

8 New results

8.1 Computational modeling of neural rhythms

8.1.1 A mathematical model to study the relative contributions and plasticity of the rod and cone pathways to the mouse retinal output

Participants: Laure Buhry, Laetitia Raison-Aubry.

Rod-mediated signals reach retinal ganglion cells (RGCs) via three major pathways with distinct sensitivities and operating ranges [1,2,3]. These pathways interact with the cone pathway to ensure seamless processing over >9 log units of light intensity [1]. Gap junctions (GJs) between rod and cone terminals, the entry point of the secondary rod pathway (SRP), exhibit circadian plasticity–stronger at night–directly modulating rod signal flow into cones, and thereby SRP influence on retinal output [4,5]. However, experimentally isolating this effect is challenging due to the non-specificity of pharmacological interventions. Biophysical modeling provides a precise and reversible alternative to selectively manipulate rod/cone coupling while preserving other synaptic conductances. Using a recent mathematical model of a retinal microcircuit [6], we investigate how circadian modulation shapes rod and cone signal integration.

Methods

Our simulated network consists of 40,000 retinal cells presynaptic to a single transient OFF alpha (tOFF a) RGC [6], arranged on a circular grid approximating the RGC's receptive field [7] and interconnected with >100,000 synaptic connections, including chemical and electrical synapses. Each retinal cell type is implemented using conductance-based models that follow the Hodgkin-Huxley formalism. Light-induced photocurrent waveforms, whose amplitude and kinetics vary nonlinearly with stimulus intensity [8], serve as input stimuli [6]. Measurements of transjunctional conductance between adjacent mouse rod/cone pairs reveal dynamic changes, ranging over 1000 pS [4,9]. To simulate circadian modulation of rod/cone coupling, we define three states for the GJ channels conductance: uncoupled (0 pS), resting/dark-adapted (300 pS), and maximally coupled (1,200 pS), in line with experimental data [4,9]. Simulations are conducted using Brian 2 [10].

Results

To evaluate the impact of circadian adaptation on retinal signal processing and RGC light responses, we compare normalized intensity-response profiles of the tOFF aRGC across rod/cone coupling states. Stimulus intensity spans the activation threshold of the primary (0.01 R*/rod/s) to the tertiary (60 R*/rod/s) rod pathways [3]. We find that, relative to the SRP resting dark-adapted range (1-60 R*/rod/s) [3], inhibiting rod/cone coupling lowers the sensitivity threshold by 0.5 log unit, while increasing coupling shifts the tOFF aRGC activation threshold 1 log unit to the right.

Discussion

Our results support a circadian shift in the threshold and relative contribution of the SRP to the retinal output. This computational approach circumvents experimental limitations, allowing precise investigation of rod/cone coupling modulation. By clarifying mechanistic links between circadian modulation and retinal sensitivity, we demonstrate that our model can be used as a theoretical framework to reconcile previous experimental inconsistencies

8.1.2 Computational and Experimental Insights into Hippocampal Slice Spiking under Extracellular Stimulation

Participants: Sarah Hamdi Cherif, Jérémie Gaidamour, Laure Buhry, Radu Ranta.

Synaptic plasticity and neuronal excitability in the hippocampus (HC) are altered in schizophrenia. Multi Electrode Array (MEA) recordings following a long-term potentiation (LTP) protocol revealed local field potential (LFP) variations along physiological pathways and high-frequency (HF) activity near the stimulation site. To understand the effect of extracellular stimulation (ES) and explore its relationship with synaptic activity and spike generation, we combined electrophysiological recordings and computational modelling. We applied ES to hippocampal slices around Schaeffer's collaterals while recording signals near CA3 pyramidal cell bodies, and we developed a computational model to aid interpretation.
In the experimental data, each ES pulse triggered a single spike, issued from the same cell according to tentative spike sorting. Lower pulse intensity led to variable latencies. As intensity increased, spike timing arose earlier and became more synchronized. According to our simulations, a cell, activated directly by ES, showed spike latencies of 0.25–4 ms that were used to parametrize the Poisson process. The target cell, excited both by ES and synaptic inputs, exhibited later and more dispersed latencies, of 3-8 ms, closer to experimental data, suggesting they capture further-layer activity. Higher intensity had the same effects as experimental data. Our findings suggest that the HF activity observed in the MEA recordings results from spiking activity propagating antidromically within CA3, activating recurrent excitatory networks.
More details in [**hamdicherif:hal-05388134**].

8.2 Confronting models and experimental data

8.2.1 From Post-Median Nerve Stimulation ERD to MI-BCI Expertise Prediction

Participants: Laurent Bougrain, Valérie Marissens Cueva *(Correspondant)*.

Predicting performance in Motor Imagery-based Brain-Computer Interfaces (MI-BCIs) is essential for identifying potential users and improving system efficiency. This study investigates whether Event-Related Desynchronization (ERD) induced by Median Nerve Stimulation (MNS) can predict a user's MI-BCI performance group (low, medium, or high) before system use. We analyzed neurophysiological features from post-MNS ERD using Linear Discriminant Analysis (LDA) and Least Absolute Shrinkage and Selection Operator (LASSO). Both achieved 74% accuracy for two-group classification (low vs. high performers), while hierarchical clustering demonstrated 83% accuracy for unsupervised classification, emphasizing MNS's discriminative power. For three-group classification, LDA performed best with 58% accuracy. Topographical analyses further revealed stronger ERD responses in motor-related areas for higher performers during both MNS and MI tasks, highlighting MNS-induced ERD as a reliable, practical

and non-invasive predictor of MI-BCI performance levels for early user stratification and advanced personalized BCI.

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

Participants: Laurent Bougrain *(Correspondant)*, Valérie Marissens Cueva.

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 [**marissenscueva:hal-05247041**].

8.2.3 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 [**mathieudecarvalho:hal-05466275**].

8.2.4 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 11.1.1)

More details in [**marissenscueva:hal-05016135**, **cueva:hal-04981146**, **marissenscueva:hal-05195827**].

8.2.5 A Two-Stage Cascaded Ensemble based on CRNN and Markov Chain for Sleep Apnea Detection using ECG

Participants: Faustine Faccin, El-Hadi Djermoune, Pauline Guyot, Laurent Bougrain.

Sleep-related irregular breathing and apnea involve periodic and cyclical decreases or interruptions in airflow, which may occur with or without obstructions of the upper airway. With nearly a billion people affected by this sleep disorder worldwide, its screening represents a major medical issue. Its early diagnosis is all the more important as numerous studies have highlighted the correlation between the presence of an untreated sleep apnea syndrome (SAS) and neurocognitive and cardiovascular consequences. Thus, in order to speed up and improve the diagnostic management of patients, researches have been conducted towards noninvasive and portable screening methods. Some of the latter are based on the patient's cardiac activity, which is closely linked to the respiratory signal and easily recordable. In this work, a new approach based on cascaded false-prediction-correcting ensemble using a hybrid deep model and Markov Chain is presented to detect sleep apnea events from nighttime long-term single-lead electrocardiograms (ECG), taken from the Apnea-ECG Database. The effectiveness of this approach is demonstrated through its capability to detect pathological ECG segments with a sensitivity, specificity and accuracy of 95.8%, 80% and 86%, respectively.

8.2.6 A Preliminary Study on Morphological Component Analysis for Arrhythmia Detection in ECG Signals from the MIT-BIH Arrhythmia Database

Participants: Faustine Faccin, Diunuge Buddhika Wijesinghe, Rena Kato, Kosei Shibata, Shabbir Mahmood, Pauline Guyot, Laurent Bougrain, Hiroaki Wagatsuma.

This study presents a preliminary explainable arrhythmia classification method using Morphological Component Analysis (MCA) and index thresholding applied to ECG signals. Cardiovascular disease remains a major global health issue, and while automated ECG analysis has advanced, data-driven AI methods often lack interpretability. We address this point by focusing on binary classification between normal beats and premature ventricular contractions using data from the MIT-BIH Arrhythmia Database. MCA decomposes ECG signals into morphological components through redundant transforms with UDWT, DST, and Dirac dictionaries. The Dirac component captures abrupt changes corresponding to the initiation of ECG cycles, while irregularities appear mainly in the UDWT component. Based on these features, an integrative classification method is proposed. The approach demonstrates high accuracy and interpretability, showing strong compatibility with model-based methods and offering potential for hybrid integration with existing arrhythmia detection frameworks.

8.2.7 Assessing Stimuli Detectability and Pleasantness for Auditory BCI

Participants: Lénaïg Guého, Laurent Bougrain, Cyril Plapous, Patrick Hénaff, Rozenn Nicol.

Brain-Computer Interfaces (BCIs) enable device control by analyzing brain activity. In reactive auditory BCIs based on steady-state auditory evoked potentials, users are exposed to amplitude-modulated sine waves at given frequencies that encode information (i.e. the type of action expected), while their brain activity is analyzed to infer the intended action based on the frequency retrieved. However, listening to sine-wave may be perceived as unpleasant over time. This study compares the use of pure-tones with alternative sounds, including artificial stimuli (such as a Brownian noise) and natural sounds (such as cicada song and cat's purr) by measuring brain responses of 48 subjects to these different stimuli, all amplitude-modulated at 40 Hz. The Signal-to-Noise Ratio (SNR) (i.e. the ratio between the power spectrum of electroencephalographic signals in response to the target stimulus and that in response to a silence stimulus) is computed at 40 Hz for each type of stimulus. It reveals that the 40-Hz modulation frequency is clearly more identifiable when carried by a pure tone than when carried by the other sounds, with an SNR increase up to more than 5 dB. The cicada song stimulus is a promising alternative, still requiring improvement to achieve the level of detectability observed for pure tones. The experiment is conducted at two different sound levels to assess whether increasing the listening level increases the SNR, but the opposite trend is found. Questionnaires indicate that more than half of the participants find pure tones annoying and prefer other sounds, confirming that this study is worth pursuing.

More details in [**gueho:biosignals_hal-05471967**]

8.2.8 An enhanced experimental paradigm for auditory BCIs by addressing both acoustic and human factors

Participants: Lénaïg Guého, Laurent Bougrain, Cyril Plapous, Patrick Hénaff, Rozenn Nicol.

This work describes an experimental paradigm designed to evaluate the usability of non-sinusoidal amplitude-modulated stimuli for Brain-Computer Interfaces (BCIs) based on steady-state auditory evoked potentials. Instead of the commonly used pure tone, which can be uncomfortable, detectability of alternatives like Brownian noise or natural sounds (e.g. cicada song and cat's purr), which are expected to be more pleasant to listen to, is assessed. Brain responses from 48 participants are recorded while listening to various amplitude-modulated sounds. To ensure accurate sound reproduction, the audio setup's frequency response is measured and compensated for, using an Head And Torso Simulator (HATS). All stimuli are also equalized in loudness to prevent perceived level differences between stimuli. Participants' hearing acuity is measured using an audiometric procedure developed for the needs of the experiment. Participants also completed questionnaires to collect information about their laterality, musicality, age and sex, as these factors may influence auditory perception.

8.2.9 Alternatives to sine carrier in auditory BCI: exploring machine learning strategies for assessing modulation detectability in EEG

Participants: Lénaïg Guého, Henrique Lefundes da Silva, Cyril Plapous, Laurent Bougrain, Patrick Hénaff, Rozenn Nicol.

In this work, the use of non-sinusoidal amplitude-modulated stimuli is assessed for Brain-Computer Interfaces (BCIs) based on Steady-State Auditory Evoked Potentials (SSAEPs). Three different stimuli are compared to the frequently used 1-kHz pure tone: Brownian noise, cicada song and cat's purr. While these alternative sounds are intended to be more pleasant for listeners, they may impact the detectability of the modulation frequency in ElectroEncephaloGraphic (EEG) signals. Stimuli are equalized in loudness using an Head And Torso Simulator (HATS). The experiment is conducted at two loudness levels (50 and 56 phons), with 24 subjects participating in each condition. Hearing capacity is assessed prior to the

experiment, using an audiometry test and questionnaires. For each stimulus, detection is performed by using 10 different classifiers: a linear discriminant analysis, deep learning networks and Riemannian classifiers including tangent space-based algorithms. These latter consistently outperformed alternative approaches. Pure tones provide the highest accuracy of detection (above 83%), whereas cicada song only achieve 60%. Classification using the proposed models fails for Brownian noise and cat's purr, with accuracy at a chance level. Additionally, increasing the loudness of the stimuli does not enhance the detectability of the modulation frequency for any stimulus. Amplitude modulation, frequency content and temporal characteristics of stimuli are further analyzed for explanation. These findings provide practical recommendations for auditory BCI classification and audio stimuli design.

More details in [**gueho2026alternatives**].

9 Bilateral contracts and grants with industry

9.1 Grants with industry

9.1.1 NOVIGA

A CIFRE thesis (see 11.2.2) began in April 2023 in collaboration with NOVIGA, a Nancy-based start-up created on the basis of research work. NOVIGA developed a CE-marked medical device for cardiologists encouraging and facilitating the early detection of sleep apnea. Indeed, sleep apnea syndrome (SAS) is a nocturnal ventilation disorder presenting long-term cardiovascular risks if untreated. Unfortunately, the gold-standard for diagnosing it is usually a burdensome and costly procedure called polysomnography. That is why NOVIGA focused on creating a screening alternative using long-term Holter electrocardiograms (ECGs) only. The purpose of the PhD is to develop a new version of the current algorithm using Deep Learning tools optimized by the fusion of physiological and clinical data in order to improve the diagnosis performance.

9.1.2 Orange Innovation

A thesis (see 11.2.2) began in April 2023 in collaboration with a R&D department at Orange Innovation in Lannion (France). Orange Innovation's mission is to efficiently produce, through research, anticipation and delivery, innovations that generate business for the Group. The Home Services department aims to make Orange the benchmark operator in these different consumer and professional broadband markets for connectivity, television, entertainment and multi-service at home by building high-performance solutions and contributing directly to the Group's CSR and security issues. The "Entertainment Services" department aims to design, build and provide entertainment and immersion services for all Orange customers with an optimal user experience. In this organization, the mission of the New User eXperience team is to invent and offer users new modes of multisensory interaction with the cyber-physical world. It relies on the expertise of its researchers and engineers. For several years, EEG signals from brain activity have also been studied.

10 Partnerships and cooperations

10.1 International initiatives

EASHRI (Collaborative project Université de Lorraine / Kyutech 2023-2025: LORIA / Department of Human Intelligence Systems)

Title: Human/Robot Social Interactions: engagement and affect analysis during gaming tasks

Duration: 2 years (Sep. 2023-Aug. 2025)

Coordinators: Tomohiro Shibata (Kyutech) Laurent Bougrain (UL)

Partners:
- Department of Human Intelligence Systems from Kyutech ;
- NeuroRhythms team/LORIA lab of université de Lorraine (UL).

Loria contact: Laurent Bougrain

Summary: This project focuses on human-robot social interaction (HRSI) and concerns the fields of robotics, neuroscience, psychology, and movement science. It aims to study the cognitive states such as engagement and emotional states of humans who interact with a robot in social games based on different hand gestures with or without physical contact. The engagement of humans and its affect will be measured through behavioral measures (motion capture) and physiological measures (electroencephalography, heart rate, skin conductance). Three different interaction experiments will be conducted with gradual physical and social interactions with the robot: rock-paper-scissors (RPS) game, rope jumping (RJ), and handshaking (HS). Different kinds of robots will be used with gradual anthropomorphism: humanoid robots, compliant arm robot with robotic hands, bi-arm compliant robots.

Project website: https://project.inria.fr/eashri/

10.2 International research visitors

10.2.1 Visits of international scientists

Hiroaki Wagatsuma

Visited institution: LORIA

Country: France

Dates: September 10 - October 12, 2025

Context of the visit: Collaborative international project Kyutech/LORIA

Mobility program/type of mobility: lecture

Rena Kato

Visited institution: LORIA

Country: France

Dates: September 10 - October 12, 2025

Context of the visit: Collaborative international project Kyutech/LORIA

Mobility program/type of mobility: lecture

Kosei Shibata

Visited institution: LORIA

Country: France

Dates: September 10, 2025 - March 9, 2026

Context of the visit: Collaborative international project Kyutech/LORIA

Mobility program/type of mobility: Research stay (visiting student)

10.2.2 Visits to international teams

Lénaïg Guého

Visited institution: Kyushu Institute of Technology (KYUTECH)

Country: Japan

Dates: February 3 - 12, 2025

Context of the visit: JST Sakura Science Program

Mobility program/type of mobility: JST Sakura Science Program

Laurent Bougrain

Visited institution: Kyushu Institute of Technology (KYUTECH)

Country: Japan

Dates: April 7 - 11, 2025

Context of the visit: JST Sakura Science Program

Mobility program/type of mobility: Erasmus+/Research stay, lectures

Hendry Ferreira Chame

Visited institution: Kyushu Institute of Technology (KYUTECH)

Country: Japan

Dates: April 7 - 11, 2025

Context of the visit: JST Sakura Science Program

Mobility program/type of mobility: Research stay

Pierre-Baptiste Mathieu de Carvalho

Visited institution: Kyushu Institute of Technology (KYUTECH)

Country: Japan

Dates: April 5- 25, 2025

Context of the visit: JST Sakura Science Program

Mobility program/type of mobility: Research stay (internship)

10.3 National initiatives

10.3.1 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-July2025

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 interact 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 clinical 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.

Projetc website: https://graspit.loria.fr

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.

Projetc website: https://project.inria.fr/anrbci4ia/

10.3.2 Programme Inria Quadrant (PIQ)

MERGES

Title: (Modélisation Et simulation d'ÉlectroRétinoGrammes pour l'Étude des mécanismes physiopathologiques de la Schizophrénie)

Duration: 48 months requested (3 phases: phase 1 - 18 months)

Coordinator: Laure Buhry (LORIA/NeuroRhythms)

Partners:
- LORIA (Lorraine Research Laboratory in Computer Science and its Applications)
- Christophe Ribelayga, Department of Optometry, University of Houston
- Steven Silverstein, department of Psychiatry, University of Rochester, USA
- Jérémie Gaidamour, IECL: HPC and software development
- Sylvain Contassot-Vivier, LORIA and software development
- Marcel Stimberg, Sorbonne University, France: software development

Loria contact: Laure Buhry

Summary: Project:

MERGES aims to identify new therapeutic targets in patients suffering from schizophrenia spectrum disorders in order to alleviate the negative and cognitive symptoms, none of which abeing relieved by current treatments. We will rely on mathematical modeling and multi-scale numerical simulation of retinal electrical activity from data collected in animals and electroretinogrammes (ERG) carried out in patients.

Scientific and technical approach:

The pathophysiological hypotheses will be tested by multi-scale mathematical modeling and numerical simulation from cellular electrophysiological and ERG recordings acquired in rodents and from ERG collected in humans under control and pathological conditions as part of an international collaboration.

Risk:

highly interdisciplinary, at the interface between numerical sciences, biology, and medicine, this project is inherently risky because it requires a lot of cross-expertise. In addition, the translation of an animal model into a human model involves intrinsic risks that will have to be addressed by comparing it with experimental data, the acquisition of which depends on these cross-collaborations.

Desired impact:

MERGES should pave the way for new treatments by identifying novel therapeutic targets and diagnostic strategies in schizophrenia spectrum disorders. In doing so, it could lead to a new nosological classification guided by etiology and not solely by the symptoms of the disorders. The retinal model developed also promises applications in the field of understanding visual perception and its pathologies.

10.4 Regional initiatives

AAP 2023 – COMPÉTENCES RECHERCHE - ACTION 15 SESRI

Project description: Sarah Hamdi-Cherif's Ph.D. is part of the **Co-SoPhoS** (Computational Modeling of the Hippocampus for the Study of PathoPhysiological Plasticity Mechanisms in an Animal Model of Schizophrenia) project financed by the 2023 call of Région Grand-Est and the Charles Hermite Federation of the University of Lorraine.

Duration: 36 months (Dec. 2023 - Dec. 2026)

Leadership: Laure Buhry.

Partners: Jérémie Gaidamour, IECL, and Radu Ranta, CRAN, in collaboration with the COMETElaboratiry in Caen, France.

Summary: This project aims to investigate the underlying pathophysiological mechanisms of schizophrenia through modeling, simulation, and multiscale signal processing with the following objectives: 1) in the short and medium term, to identify new therapeutic targets; 2) to propose new treatments that are more effective across the full spectrum of symptoms and better personalized within the framework of precision medicine.

It is also important to note that our modeling and simulation approach will help address a major challenge, namely the reduction and "refinement," or even "replacement," of the use of animals in experimentation, as required at the French and European levels by the 3Rs rule. These digital techniques indeed make it possible to test hypotheses *in silico* before confirming only the plausible ones *in vitro* or *in vivo*, whether they concern pathophysiological mechanisms or the effects of pharmacological substances.

11 Dissemination

11.1 Promoting scientific activities

11.1.1 Scientific events: organisation

Member of the organizing committees: V Marissens Cueva, 11th BCI Meeting 2025 workshop on Exploring the clinical integration of BCI technology in general anesthesia monitoring, Banff, Canada

General chair, scientific chair

- 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

- Sarah Hamdi Cherif, Valérie Marissens Cueva, Faustine Faccin: PhD Students' Day of D5 Department, LORIA.

11.1.2 Scientific events: selection

Chair of conference program committees

Member of the conference program committees

Reviewer

- Faustine Faccin: review of one communication for the national colloquium Gretsi.
- Laurent Bougrain : CORTICO 2025, Vistual Reality 2025

11.1.3 Journal

Member of the editorial boards

Reviewer - reviewing activities

- Laurent Bougrain served as reviewer for Brain Topography, Virtual Reality'25, Cortico'25

11.1.4 Invited talks

- 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

11.1.5 Leadership within the scientific community

- Laurent Bougrain is a member of the Board of Directors of the scientific society CORTICO for the promotion of Brain-Computer Interfaces in France.

11.1.6 Scientific expertise

11.1.7 Research administration

11.2 Teaching - Supervision - Juries

11.2.1 Teaching

- Engineering school: Valérie Marissens Cueva, *Artificial Intelligence*, 32h eqTD, 2nd year, Télécom Nancy, Nancy, France.
- Engineering school: Sarah Hamdi Cherif, *Artificial Intelligence*, 28h eqTD, 2nd year, Télécom Nancy, Nancy, France.
- Engineering school: Sarah Hamdi Cherif, *Modeling of Signals and Systems*, 18h eqTD, 1st year, ENSEM, Nancy, France.
- Engineering school: Sarah Hamdi Cherif, *Control Theory*, 9h eqTD, 1st year, ENSEM, Nancy, France.
- Engineering school: Sarah Hamdi Cherif, *Computer Science*, 9h eqTD, 1st year, ENSEM, Nancy, France.
- Master: Valérie Marissens Cueva, *Brain-Computer Interfaces*, 17h eqTD, M2 Cognitive science IDMC, Université de Lorraine, Nancy, France.
- Master: Valérie Marissens Cueva, *Scientific Protocols*, 5h TD + 5h CM, M2 Cognitive science IDMC, Université de Lorraine, Nancy, France.
- Laurent Bougrain, *Brain-computer Interfaces* and *Signal processing and machine learning of electroencephalographic Signals* (8h CM), Licence and Master in Life Science and Systems Engineering, Kyushu Institute of Technology (Kyutech), Kitakyushu-shi, Fukuoka, Japan
- Laure Buhry, *Computational Neurosciences*, M2 Cognitive Science, IDMC and *IA pour la santé*, FASM3, Faculté de Médecine de Nancy.

11.2.2 Supervision

- PhD Theses
  - PhD in progress: Lénaïg Guého, Design and evaluation of a brain-computer interface using spatialized auditory stimuli, March 30 2023, Patrick Hénaff, Rozenn Nicol (Orange Innovation), Laurent Bougrain and Cyril Plapous. (Orange Innovation).
  - PhD in progress: Faustine Faccin, Merge of clinical information in a neural network for the optimization of the diagnostic performance of sleep apnea syndrome, March 30 2023, El-Hadi Djermoune (CRAN), Laurent Bougrain and Pauline Guyot (Noviga).
  - PhD in progress: Valérie Marissens Cueva, Detection of intraoperative awareness from electroencephalographic signals: towards the design of an innovative brain-computer interface, December 1st 2023, Fabien Lotte (Inria Bordeaux), Laurent Bougrain and Sébastien Rimbert (Inria Bordeaux).
  - PhD in progress: Sarah Hamdi Cherif, Biologically realistic computational modelling of the hippocampal electrical activity and plasticity for the study of the pathophysiological mechanisms of schizophrenia, December 5th 2023, Laure Buhry, Radu Ranta (CRAN) and Jérémie Gaidamour (IECL)
  - PhD in progress: Laëtitia Raison-Aubry, Mathematical modeling of electrical retinal activity: application to the study of pathophysiological mechanisms in psychiatry and the development of new therapeutic targets, October 1st 2021, Laure Buhry.
- Master Theses
  - Pierre-Baptiste Mathieu de Carvalho: co-supervised by Laurent Bougrain & Marie-Constance Corsi (April-Aug. 2025)
- Bachelor Theses
  - Aymane Benamar: co-supervised by Laetitia Raison-Aubry & Sarah Hamdi Cherif (April-June. 2025)
  - Achille Richard-Calvo: co-supervised by Laetitia Raison-Aubry & Sarah Hamdi Cherif (April-June. 2025)

11.2.3 Juries

- 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
- Laure Buhry, Examiner, PhD committee of Jeanne Barthélémy Sorbonne University, SEptember 15, 2025, Paris, France

11.3 Popularization

11.3.1 Internal or external responsibilities

11.3.2 Articles and contents

11.3.3 Education

11.3.4 Interventions

- 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.

12 Scientific production

12.1 Major publications

[0] N. Azevedo Carvalho, S. Contassot-Vivier, L. Buhry and D. Martinez. 'Simulation of Large Scale Neural Models With Event-Driven Connectivity Generation'. In: *Frontiers in Neuroinformatics* 14 (Oct. 2020), p. 14. DOI: 10.3389/fninf.2020.522000. URL: https://hal.science/hal-03041616.

[0] M. Clerc, L. Bougrain and F. Lotte. *Brain-Computer Interfaces 1*. Ed. by M. Clerc, L. Bougrain and F. Lotte. Wiley-ISTE, July 2016. URL: https://inria.hal.science/hal-01408991.

[0] J. Doe. 'Computer science beyond the realm of reason'. In: *The journal* (2020). URL: https://hal.inria.fr/hal-02886.

[0] C. Tremblay. 'Old paper'. In: *The other journal* (2000).

12.2 Publications of the year

International journals

[0] S. Hamdi Cherif and M. A. Brahami. 'Efficient and fast pipelines leak localization using inverse transient analysis: A particle swarm optimization algorithm-based approach'. In: *Arabian Journal for Science and Engineering* (20th Aug. 2024). DOI: 10.1007/s13369-024-09472-x. URL: https://hal.univ-lorraine.fr/hal-04835247.

[0] A. P. MendonÃ§a Fernandes, L. J. de Holanda, L. Coutinho De Lucena, K. E. R. Da Silva, A. C. S. M. Lopes, D. T. Borges, D. Nagem, R. Valentim, L. Bougrain and A. R. R. Lindquist. 'Electromyography as a tool to motion analysis for people with Amyotrophic Lateral Sclerosis: A protocol for a systematic review'. In: *PLoS ONE* 19.5 (28th May 2024), e0302479. DOI: 10.1371/journal.pone.0302479. URL: https://hal.univ-lorraine.fr/hal-04756750.

[0] K. Yamasaki, S. Tomohiro and P. Henaff. 'Individual adaptation and social attributes in a handshake robot with CPG control'. In: *Advanced Robotics* 0.0 (7th Aug. 2024), 1â€“16. DOI: 10.1080/01691864.2024.2384422. URL: https://hal.science/hal-04674318.

[0] K. Yamasaki, S. Tomohiro and P. Henaff. 'Personalized Assist-As-Needed Dressing Assistance Robot without HumanModeling using Rowat-Selverston CPG Controller'. In: *Advanced Robotics* 38.19-20 (2024), 1408â€“1423. URL: https://hal.science/hal-04674349.

International peer-reviewed conferences

[0] F. Faccin, E.-H. Djermoune, L. Bougrain and P. Guyot. 'ECG-based deep convolutional recurrent network with attention mechanism for sleep apnea detection'. In: Computing in Cardiology. Karlsruhe, Germany, 8th Sept. 2024. URL: https://hal.science/hal-04730104.

[0] H. Ferreira Chame and R. Alami. 'AEGO: Modeling Attention for HRI in Ego-Sphere Neural Networks'. In: 2024 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS). Abu Dhabi, United Arab Emirates, Oct. 2024. URL: https://hal.science/hal-04682884.

[0] V. Marissens Cueva, S. Rimbert, A. M. Cebolla Alvarez, M. Petieau, V. Vitkova, I. Hashemi, G. Cheron, C. Meistelman, P. Guerci, D. Schmartz, S. J. Bidgoli, L. Bougrain and F. Lotte. 'Towards Riemannian EEG classifiers to detect awake and anesthetized states using median nerve stimulation'. In: 9th International Graz Brain-Computer Interface Conference 2024. Graz, Austria, 9th Sept. 2024. URL: https://hal.science/hal-04634725.

[0] S. Rimbert, V. Marissens Cueva, L. Bougrain and F. Lotte. 'Prediction of Motor-Imagery-BCI performance using Median Nerve Stimulation'. In: BCI 2024 - The 12th International Winter Conference on Brain-Computer Interface. Seoul, South Korea, 31st Jan. 2024. URL: https://inria.hal.science/hal-04428894.

[0] K. Yamasaki, S. Tomohiro and P. Henaff. 'Social Attributes in a Handshake Robot Adaptive to Human Shaking Motion Using a CPG Controller'. In: The 33rd IEEE International Conference on Robot and Human Interactive Communication, IEEE RO-MAN 2024. Passadena, CA, United States, 30th Aug. 2024. URL: https://hal.science/hal-04606905.

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Conferences without proceedings

[0] I. Casso, H. Ferreira Chame, P. Henaff and Y. N. Delevoye-Turrell. 'Exploring Engagement in Human-Robot Interaction through the Quantification of Human Spontaneous Movement'. In: The 33rd IEEE International Conference on Robot and Human Interactive Communication - IEEE RO-MAN 2024. Pasadena (CA), United States, 30th Aug. 2024. DOI: 10.1109/RO-MAN60168.2024.10731439. URL: https://hal.science/hal-04606893.

[0] S. Hamdi Cherif, H. Ferreira Chame and L. Bougrain. 'Human-robot social interaction: A rock-paper-scissors protocol for mental states analysis and gesture prediction'. In: Journées du Collectif pour la Recherche Transdisciplinaire sur les Interfaces Cerveau-Ordinateur, CORTICO 2024. Nancy, France, 22nd May 2024. URL: https://hal.univ-lorraine.fr/hal-04834810.

[0] V. Marissens Cueva, S. Rimbert, A. M. Cebolla Alvarez, M. Petieau, I. Hashemi, V. Vitkova, G. Cheron, C. Meistelman, P. Guerci, D. Schmartz, S. J. Bidgoli, L. Bougrain and F. Lotte. 'One-Class Riemannian EEG Classifier to Detect Anesthesia'. In: 5th International Neuroergonomics Conference 2024. Bordeaux, France, 8th July 2024. URL: https://hal.science/hal-04634709.

[0] V. Marissens Cueva, S. Rimbert, A. M. Cebolla Alvarez, M. Petieau, V. Vitkova, I. Hashemi, G. Cheron, C. Meistelman, P. Guerci, D. Schmartz, S. J. Bidgoli, L. Bougrain and F. Lotte. 'Median Nerve Stimulation to Detect Awake and Anesthetized States with Riemannian Classifiers'. In: JournÃ©es CORTICO 2024 - COllectif pour la Recherche Transdisciplinaire sur les Interfaces Cerveau-Ordinateur. Nancy, France, 22nd May 2024. URL: https://hal.science/hal-04570975.

Doctoral dissertations and habilitation theses

[0] A. G. Herrera. 'Vibrotactile feedback to support kinesthetic motor imagery in a brain-computer interface for post-stroke motor rehabilitation'. UniversitÃ© de Lorraine, 10th Jan. 2024. URL: https://hal.univ-lorraine.fr/tel-04540310.

Reports & preprints

[0] C. Thillier, E. Parsy, L. Charles, P.-B. Mathieu De Carvalho, L. Bougrain and L. R. Lindquist. *Conception d'une interface cerveau-ordinateur pour contribuer Ã la communication de patients atteints d'une sclÃ©rose latÃ©rale amyotrophique*. Loria; IDMC (UniveristÃ© de Lorraine), 19th Jan. 2024. URL: https://hal.science/hal-04521816.

Other scientific publications

[0] I. Casso, H. Ferreira Chame, P. Henaff and Y. N. Delevoye-Turrell. 'Sorry I overreacted: The role of Affect in the Modulation of Motor Resonance during Face-to-Face Interaction'. In: The European Society for Cognitive and Affective Neuroscience. Ghent (BE), Belgium, 22nd May 2024. URL: https://hal.science/hal-04606872.

[0] F. Faccin, E.-H. Djermoune, P. Guyot and L. Bougrain. 'Multimodal data fusion for brain-computer interfaces: A literature review'. In: JournÃ©es CORTICO (COllectif pour la Recherche Transdisciplinaire sur les Interfaces Cerveau-Ordinateur). Nancy, France, 22nd May 2024. URL: https://hal.science/hal-04636122.

[0] L. Gueho, C. Plapous, R. Nicol, P. Henaff and L. Bougrain. 'Evaluation de stimulations sonores pour amÃ©liorer le confort utilisateur et leur dÃ©tection par une ICO auditive'. In: CORTICO 2024. NANCY, France, 22nd May 2024. URL: https://hal.science/hal-04631298.

[0] S. Hamdi Cherif, C. Roux, V. Bouet, J.-M. Billard, J. Gaidamour, L. Buhry and R. Ranta. 'Investigating hippocampal synaptic plasticity in schizophrenia: A computational and experimental approach using MEA recordings'. In: Bernstein Conference. Frankfurt, Germany, 29th Sept. 2024. DOI: 10.12751/nncn.bc2024.244. URL: https://hal.univ-lorraine.fr/hal-04835241.

[0] P.-B. Mathieu de Carvalho, L. Charles, E. Parsy, A. R. R. Lindquist and L. Bougrain. 'A Hybrid BCI based on SSVEP and Gaze Direction Recognition: Towards a Speller for Patients with Amyotrophic Lateral Sclerosis'. In: CORTICO 2024. Nancy, France, 22nd May 2024. URL: https://hal.science/hal-04630176.

[0] K. Yamasaki, T. Kajiwara, T. Shibata and P. Henaff. 'Realizing a Personal Adaptive Dressing Assistance Robot'. In: IEEE International Conference on Robotics and Automation ICRA2024. Yokohama Japan, Japan, 13th May 2024. URL: https://hal.science/hal-04557303.

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[0] C. Kerr, S. Van Albada, S. Neymotin, G. Chadderdon, P. Robinson and W. Lytton. 'Cortical information flow in Parkinson's disease: a composite network/field model'. In: *Frontiers in Computational Neuroscience* 7 (2013), p. 39. DOI: 10.3389/fncom.2013.00039. URL: https://www.frontiersin.org/article/10.3389/fncom.2013.00039.

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