RIDC NeuroMat

Twelfth Report of Activities

Aug 01, 2024 - Jul 31, 2025

Contents

1 RIDC NeuroMat Identification

RIDC: Research, Innovation and Dissemination Center for Neuromathematics (NeuroMat)

Grant number: 2013/07699-0

Host institution: Instituto de Matemática e Estatística da Universidade de São Paulo

Associated institutions: Aalto University; Centre National de la Recherche Scientifique - CNRS (Strasbourg); Forschungszentrum Jülich; National Institute of Neurological Disorders and Stroke (NIH); Universidad de Buenos Aires; Universidad de San Andrés; Universidade Estadual de Campinas (UNICAMP); Universidade Federal do ABC (UFABC); Universidade Federal do Rio de Janeiro (UFRJ); Universidade Federal do Rio Grande do Norte (UFRN); Universidade Federal de São Carlos (UFSCar); Universidade Federal de São Paulo (UNIFESP); Università di Roma "La Sapienza"; Université Côte d'Azur; Université Paris 1 (Pantheon-Sorbonne); University of California, Berkeley.

Webpage: http://neuromat.numec.prp.usp.br

Principal Investigator/Center Director: Oswaldo Baffa Filho (USP)

Vice Director: Pablo Augusto Ferrari (USP and UBA)

Co-Principal Investigators: Antônio Carlos Roque da Silva Filho (USP); Claudia Domingues Vargas (UFRJ); Fernando Jorge da Paixão Filho (UNICAMP); Florencia Graciela Leonardi (USP); Osame Kinouchi Filho (USP); Maria Elisa Pimentel Piemonte (USP)

Associate Investigators: Alexsandro Giacomo Grimbert Gallo (UFSCar); Aline Duarte de Oliveira (USP); Anatoli Iambartsev (USP); André Frazão Helene (USP); André Fujita (USP); Christophe Pouzat (Université Paris Descartes); Daniel Fraiman Borrazás (Universidad de San Andrés); Daniel Yasumasa Takahashi (UFRN); Eduardo Vicente (USP); Eva Loecherbach (Université Paris 1 - Pantheon-Sorbonne); Fernando Araújo Najman (UFABC); Guilherme Ost de Aguiar (UFRJ); João Alexandre Peschanski (Wikimedia); Kelly Rosa Braghetto (USP); Marcela Svarc (Universidad de San Andrés); Marzio Cassandro (Università di Roma "La Sapienza"); Morgan Florian Thibault André (USP); Patricia Reynaud-Bouret (Université Côte d'Azur); Rafael Bassi Stern (USP); Raquel de Paula Carvalho (UNIFESP)

Innovation Coordinator: Antônio Carlos Roque da Silva Filho (USP)

Education and Knowledge Dissemination Coordinator: Fernando Jorge da Paixão Filho (UNICAMP)

Administrative assistant: Lourdes Vaz da Silva Netto (IME/USP)

International Advisory Board: David Brillinger (UCBerkeley), Francesco Guerra (Universita di Roma "La Sapienza"), Leonard Cohen (NIH), Markus Diesmann (Forschungszentrum Jülich), and Wojciech Szpankowski (Purdue and NSF Center for Science of Information).

The Research, Innovation and Dissemination Center for Neuromathematics (RIDC NeuroMat) is a center of mathematics which has as mission to develop the new mathematics needed to construct a Theory

of the Brain accounting for the experimental data gathered by neuroscience research. Antonio Galves coordinated the center until his death on September 5, 2023, and Oswaldo Baffa has been coordinating it since October 4, 2023. Hosted by the University of São Paulo, the RIDC NeuroMat was established in 2013, with support from the São Paulo Research Foundation (FAPESP), grant 2013/07699-0, which will last until July 2026.

The RIDC NeuroMat has an interdisciplinary team, bringing together researchers in mathematics, statistics, physics, computer science, neuroscience, biology, physiotherapy, medicine and communication, among other disciplines. RIDC NeuroMat leads a worldwide university network, with ramifications that sprawl to several high-level research institutions in Brazil, Latin America, the United States, Europe and China (Annex 1). Most research output has had co-authors from more than one country, thus contributing to put NeuroMat at the center of a blossoming international scientific cooperation around Neuromathematics.

Alongside a research team that focuses on the scientific challenges pertaining to Neuromathematics, NeuroMat has active innovation and dissemination teams. The innovation effort is concentrated on devising tools for diagnosing and clinical guidelines for two major neurological conditions, Parkinson's disease (PD) and brachial plexus injury (BPI). The NeuroMat's activities related to these two conditions are conducted by the NeuroMat-borne initiatives AMPARO (Rede de Apoio NeuroMat a Amigos e Pessoas com Doença de Parkinson) and ABRAÇO (Ação NeuroMat para a Lesão do Plexo Braquial).

The dissemination team effort includes a nonstatic web portal (Creative Commons license), open multimedia productions and training projects with public-school teachers. A distinctive feature of this effort is that it relies on web-2.0 media tools as a means of communicating on-the-go scientific endeavors as well as involving a scientific and broad community around bridging the high-level science that this RIDC develops and general audiences.

NeuroMat's main laboratory and offices are located on a three-story building (the Antonio Galves building), with approximately 1,175 square meters, at 1171 Prof. Luciano Gualberto Avenue, at USP's central campus, in São Paulo. NeuroMat has three laboratory facilities: an Electroencephalography Laboratory (EEG Lab) at its main building in São Paulo; a Simulation Laboratory (SimLab) and a Transcranial Magnetic Stimulation Laboratory (TMS Lab) equipped with a robotic arm at the USP Ribeirão Preto campus. Multiuser experimental facilities in São Paulo and Ribeirão Preto are being planned. NeuroMat's administrative staff team is composed of one administrative assistant. This position is supported by USP.

2 Scientific report

2.1 Mission

The main mission of NeuroMat is to develop the new mathematics which is deemed necessary to account for a Theory of the Brain, accounting for the full experimental data gathered by neuroscience research. The long-term objective is to understand and explain complex neuroscientific phenomena, with focus on plasticity mechanisms underlying learning and memory neurorehabilitation and rewiring. This Neuromathematics is envisioned, at this time, as conjoining probability theory, combinatorics, statistics, and neuroscience. This requires the definition of a full new class of mathematical models to describe and explain in a parsimonious way the different scales of neural activity and the relationship between them. The construction of these models should occur together with the development of suitable statistical and computational methods, including model selection principles and results.

2.2 Executive summary

The main goals of NeuroMat are as follows:

1. Development of new classes of stochastic processes to describe spiking neural networks;
2. Development of a new mathematical approach to address the classical conjecture that the brain retrieves statistical regularities from sequences of stimuli (the "statistician brain" conjecture);
3. Development of new computational models of brain processes and structures;
4. Development of neurobiological and clinical applications of the theoretical tools created by the center.

The first two research lines, of a formal mathematical nature, were led from NeuroMat's inception by its director, Antonio **Galves**, until his premature passing in September 2023. Since then, these lines have been carried forward by principal investigator Florencia **Leonardi** (IME-USP) and associated investigators Morgan **André** (IME-USP), Aline **Duarte** (IME-USP), Alexsandro **Gallo** (UFS-Car), Eva **Löcherbach** (Panthéon-Sorbonne), Fernando **Najman** (UFABC), Christophe **Pouzat** (CNRS-Strasbourg), Marcela **Svarc** (UBA), and Guilherme **Ost** (UFRJ). The third line, with a more computational orientation, has been conducted by principal investigators Osame **Kinouchi** and Antonio **Roque** (both from FFCLRP-USP). The fourth line, which focuses on the neurobiological applications of the mathematical tools developed by the center, has been led by principal investigators Maria Elisa **Piemonte** (FM-USP) and Cláudia **Vargas** (UFRJ) in the contexts of the AMPARO and ABRAÇO initiatives, respectively. This line involves the development of new protocols for brain stimulation and clinical assessment, positioning it at the interface between research and innovation. One such protocol employs

sequences of transcranial magnetic stimulation (TMS) pulses driven by context trees, which must be delivered with a high degree of accuracy. To this end, NeuroMat's Director and principal investigator Oswaldo **Baffa**, in collaboration with Risto Ilmoniemi (Aalto), has been leading the development of a robotic arm system designed to automate and precisely control the positioning of TMS coils on the scalp during stimulation.

In the remainder of this text, to facilitate the fluidity of reading, the NeuroMat researchers mentioned above will be referred to by their surnames, highlighted in bold.

Since the "Eleventh Report of Activities", the NeuroMat research team has:

- published 41 papers;
- submitted 7 online pre-prints;
- presented 3 communications in meetings with referees;
- published 1 book;
- had 2 PhD theses concluded and 9 in progress;
- had 4 MSc dissertations in progress.

The scientific publications during the period assessed in this report are listed on Annex 2. A full list of publications since the inception of NeuroMat can be viewed at NeuroMat's Google Scholar (https://goo.gl/LvZV4f). Citations to these publications across the years are available on Annex 3.

The following section presents the highlights of the four research lines over the past year.

2.3 Research results highlights

2.3.1 First research line: stochastic processes for spiking neural networks

- **Book with a comprehensive synthesis of NeuroMat's research on stochastic spiking neuronal networks.** NeuroMat's fundamental contribution to the first line of research was the introduction, twelve years ago (Galves and Löcherbach, 2013), of a new class of stochastic point processes with variable-length memory to model spiking neuronal networks. Over the years, thanks to the work of NeuroMat itself and of other researchers, this class of stochastic processes has become a well-established field of study within Probability Theory and Neuromathematics. The growth and significance of this research area reached a level that justified the writing of a book to consolidate its advances. This was the purpose of the book Probabilistic Spiking Neuronal Nets: Neuromathematics for the Computer Era, by Galves, Löcherbach and Pouzat, published at the end of 2024. The book was initiated while Galves was still alive and completed by his two main international collaborators in this line of research. It provides an accessible yet mathematically rigorous and

biologically grounded introduction to the new class of stochastic processes for spiking neuronal networks introduced by NeuroMat. The volume presents a comprehensive synthesis of the developments achieved over the past twelve years, including discrete-time and continuous-time models, methods for inferring the interaction graph of a network from samples of neuronal spike trains, and the effects of short-term synaptic plasticity on network stability.

- **Löcherbach's collaborative visit to NeuroMat.** In December 2024, Löcherbach visited NeuroMat for two weeks, delivering a talk at the workshop Random Graphs in the Brain II titled *What does the mean field limit tell us about interacting neuronal systems?* During her stay, she engaged in research discussions with Duarte and NeuroMat's postdoctoral fellow Kadmo Laxa on two central questions: (i) statistical insights from the mean field limit, leading to the preprint Non-parametric estimation of the jump rate in mean field interacting systems of neurons, by Duarte, Laxa, Löcherbach and Loukianova (submitted to the journal Mathematical Neurosciences and Applications); and (ii) the feasibility of perfect simulation in large systems of interacting spiking neurons, work currently being finalized in an article co-authored with Laxa and Emilio De Santis (Roma "La Sapienza").

- **Optimal likelihood-based methods for community detection and model selection in stochastic block network models.** In collaboration with Gallo and other colleagues from UFSCar, Leonardi developed and analyzed maximum and integrated likelihood criteria for community detection in the stochastic block model, proving their optimality at the phase transition threshold in the semi-sparse regime, and proposed an information-theoretic method for consistent selection of the number of communities in the degree-corrected stochastic block Model. These resulted in the preprint Optimal recovery by maximum and integrated conditional likelihood in the general Stochastic Block Model, by Cerqueira and Leonardi, and the article Consistent model selection for the degree corrected stochastic blockmodel, by Cerqueira, Gallo, Leonardi and Vera.

2.3.2 Second research line: "statistician brain" conjecture

- **New statistical tool reveals how the brain encodes rhythmic sequences.** NeuroMat has developed a rigorous probabilistic framework to investigate the "statistician brain" conjecture, which posits that that the brain extracts statistical regularities from sequences of stimuli. This framework is described in NeuroMat's foundational papers, (Duarte et al., 2019), which introduced a new stochastic process that jointly models sequences of auditory stimuli and the corresponding EEG responses, and (Hernández et al, 2021), which demonstrated that electrophysiological signatures of stochastic chains generating auditory sequences can indeed be retrieved from EEG data. Data from the second foundational paper were revisited in the article Extracting the fingerprints of sequences of random rhythmic auditory stimuli from electrophysiological data by Najman, Galves,

Svarc and Vargas (2025), which introduced a new statistical clustering tool and applied it to EEG recordings from participants listening to stochastic samba-like rhythms. The authors show in the article that the brain relies on the recurrent strong beat to encode and segment the sequence. This work represents a major advance in the "statistician brain" conjecture, providing novel evidence on how the brain organizes sensory input to predict future events.

2.3.3 Third research line: computational models

- **Hierarchical modular networks of Galves-Löcherbach neurons.** A research line led by Kinouchi and Roque explores the applications of the Galves–Löcherbach (GL) model to the study of the critical brain hypothesis, which suggests that neural systems operate near critical points to optimize information processing and adaptability. The GL model provides a mathematically tractable framework to investigate statistical properties of spiking activity and to test whether signatures of criticality, e.g. neuronal avalanches, emerge naturally in neural network models (Brochini et al, 2016). In previous works by the NeuroMat team, the GL model was used to investigate the dynamics of neural networks with various topologies, but none of them considered networks with a hierarchical and modular (HM) structure. This gap was addressed in the article Influence of topology on the critical behavior of hierarchical modular neuronal networks by the NeuroMat postdoc Flavio Rusch, Kinouchi, and Roque (2025). They showed that GL networks with hierarchically organized modules self-organize more robustly toward criticality. Hierarchical modularity reduces the impact of perturbations when modules follow Erdős–Rényi or K-nearest-neighbor topologies, but not when modules are fully connected, where excessive connection density overrides modularity benefits.

- **Astrocyte model suggests dopamine's role in amplifying and organizing astrocytic responses to glutamate.** In his lecture on Mathematical Neuroscience, delivered on October 25, 2022, as part of the virtual seminar series Pathways to the 2023 IHP thematic program Random Processes in the Brain organized by NeuroMat, Olivier Faugeras (INRIA-Côte d'Azur;) urged neuromathematicians to develop models of glial cells—particularly astrocytes—in order to account for the important functional roles of these cells that have been recently uncovered by experimental research. This lecture was one of the stimuli that led Roque to initiate a new research line in the SimLab focused on computational modeling of astrocytes. The first NeuroMat article in this new line of research, Dopamine facilitates the response to glutamatergic inputs in astrocyte cell models, authored by NeuroMat doctoral student Thiago Ohno Bezerra and Roque, was published at the end of 2024. It introduced detailed and reduced computational models of astrocytes to study their responses to glutamate and dopamine. The study showed that dopamine not only amplifies astrocytic responses to glutamate but also spatially organizes these responses within the cell, sug-

gesting a key role in information integration and network synchronization. The reduced model can be studied via dynamical systems tools and enables large-scale simulations, offering an efficient tool for incorporating astrocytes into neural network studies.

2.3.4 Fourth research line: neurobiological and clinical applications

- **Advancing TMS methodologies for investigating plasticity in BPI.** A central research goal of NeuroMat, led by Baffa and Vargas, is to establish a novel TMS-based protocol to study mechanisms of brain plasticity following BPI. While no article specifically addressing this new protocol was published in the reporting period, important progress was achieved through the technical collaboration between Baffa and Ilmoniemi on robotic control of multilocus TMS (mTMS) coil positioning. These advances are critical enablers for the BPI research line, as they address the main experimental challenge of ensuring precise, stable, and reproducible TMS coil placement during stimulation. The collaboration resulted in the development of an autonomous robotic mTMS positioning system that automates procedures such as hotspot hunting and motor mapping, achieving submillimeter accuracy and outperforming manual positioning. This work was consolidated in two major publications: Probing the orientation specificity of excitatory and inhibitory circuitries in the primary motor cortex with multi-channel TMS (Souza et al., 2025), which examined the orientation dependence of excitatory and inhibitory circuitries, and Characterizing an electronic–robotic targeting platform for precise and fast brain stimulation with multi-locus transcranial magnetic stimulation (Matsuda et al., 2025), which demonstrated the precision and autonomy of the NeuroMat system. In addition, Baffa presented the most recent advances at the 6th Brain Stimulation Congress (Kobe, Japan, 2025), showcasing for the first time dual-site TMS using two robotic arms guided by tractography-based neuronavigation, opening new avenues for the study of interhemispheric brain communication.

- **AMPARO conducts first comprehensive survey on sexual health of people with PD in Brazil.** The AMPARO team led by Piemonte published two epidemiological studies that marked a significant advance in understanding the sexual health of people with PD in Brazil: The impact of motor, non-motor, and social aspects on the sexual health of men living with Parkinson's disease (Souza et al., 2024) and The impact of motor, non-motor, and social aspects on the sexual health of women living with Parkinson's disease (Nóbrega et al., 2025). The research revealed how biological, psychological, and social factors—ranging from self-esteem and affective relationships to motor and non-motor symptoms, as well as cultural conditions—shape sexual health experiences, filling a critical gap in an area scarcely explored worldwide and virtually absent in the Brazilian context. Data collection included self-identified individuals from four racial groups across all five Brazilian regions, an unprecedented achievement enabled by the AMPARO network.

2.4 Scientific meetings organized by NeuroMat in the period

An important aspect of the work NeuroMat produces depends on fostering a tight relationship among members of the NeuroMat community worldwide. As emphasized in our interaction with FAPESP International Committee, we are especially aware of this challenge, and we have sustained partnerships among scientists from different parts of the world — of which the high rate of papers with co-authors from different countries is an evidence. The fostering of a tight community around Neuromathematics strongly meets the expectations of FAPESP's Committee.

A key part of the community-building entrepreneurship NeuroMat has sustained relates to organizing frequent conferences and meetings on topics pertaining to Neuromathematics. In the period covered by this report, we continued with this endeavor and the meetings, training and seminar activities organized are listed below.

- Random Graphs in the Brain II. The workshop was held at the Antonio Galves building in November 18 and December 9, 2024. This two-day workshop was a sequel to a workshop with the same title held in 2015. The first workshop paved the way for the research program conducted within NeuroMat. In the second edition, the purpose was to revisit the core topics of the first workshop and discuss novel approaches to model cognitive learning and community detection within neuronal networks.

- NeuroMat seminars. NeuroMat maintains a regular program of monthly seminars to disseminate research results both from its own researchers and from invited scholars. The list of seminars held during the reporting period is presented in Annex 7.

3 Innovation report

A central focus of NeuroMat's innovation efforts has been the development of technological tools that support diagnosis and neuro-rehabilitation, particularly in connection with the AMPARO initiative on PD and the ABRAÇO initiative on BPI. Among the key innovations are the Goalkeeper Game, a digital tool for cognitive assessment; the robotized TMS positioning system; and the Neuroscience Experiments System (NES), an open-source platform for data acquisition and management. Details and links to the GitHub repositories of these and other NeuroMat-developed tools are available on NeuroMat's Intellectual Property webpage.

3.1 ABRAÇO Initiative

NeuroMat's BPI focus area is called ABRAÇO Initiative, or Ação NeuroMat para a Lesão do Plexo Braquial. The ABRAÇO website is the first worldwide platform devoted to this health condition and is aimed at being both a source of help and support for patients, caregivers, students and professionals, and a powerful scientific knowledge sharing platform. ABRAÇO is led by Vargas.

3.1.1 Assessing plasticity associated to BPI

The ABRAÇO team is conducting experimental protocols with human subjects that employ both the Goalkeeper Game (Section 3.3.1) and TMS pulses (Section 3.4.1) to investigate brain plasticity mechanisms following traumatic BPI, aiming to develop new assessment and rehabilitation strategies. With the Goalkeeper Game, the focus is on identifying parameters of its stochastic sequences that best reflect optimal motor event processing. With TMS pulses, the goal is to determine whether the motor evoked potential (MEP) can retain a detectable signature of a sequence of stimuli applied to the primary motor cortex (M1). Together, these innovative approaches may yield powerful tools for advancing the understanding and rehabilitation of BPI.

3.2 AMPARO Initiative

The NeuroMat focus area towards PD is called AMPARO Initiative, or Rede de Apoio NeuroMat a Amigos e Pessoas com Doença de Parkinson. The AMPARO website is a reference source on PD in Brazil, providing scientific and practical information, case histories and questions and answers for people with PD, their relatives and caregivers. AMPARO is led by Piemonte.

3.2.1 A tool for early PD assessment

The AMPARO team is using the Goalkeeper Game (Section 3.3.1) to study putative novel relationships between the main cardinal PD symptom, bradykinesia, and implicit probabilistic learning and lack of ability in automatic motor control. The objective is to develop a new measure and typology to establish the limits between normal decline associated to aging process and abnormal alterations associated to

the onset of the pathological process of PD. The clinical implication of this work is to offer a free and friendly test to early diagnosis of PD.

3.3 Computational tools

3.3.1 Goalkeeper Game

NeuroMat researchers devised experimental protocols to test the performance of human subjects in identifying sequences of stimuli represented by context trees. An innovation spin-off from NeuroMat's research project is the "Goalkeeper Game". It is an online game with desktop and mobile device versions in which the player, taking the role of a goalkeeper in a penalty shootout, guesses the position in the goal where the ball will hit (left side, right side or center) after being kicked by the opponent. The game consists in a sequence of penalty kicks in which the ball positions are generated by a context tree model. As the player (the goalkeeper) succeeds in guessing the right sequence, the complexity of the context tree model increases and the game becomes more difficult. The goalkeeper game has potential to be used as diagnosis and rehabilitation tool in neurology, and the NeuroMat innovation team is currently testing its applicability in its two main clinical development fronts: BPI and PD (see Sections 3.1.1 and 3.2.1). The game is openly, freely available at: game.numec.prp.usp.br and also at Apple Store and Google Play.

The current development of the Goalkeeper Game is under the coordination of NeuroMat's Associate Investigator Kelly Rosa **Braghetto** (IME/USP). To meet the research requirements of ABRAÇO and AMPARO and ensure long-term software maintenance, the team led by Braghetto developed a new version of the Goalkeeper Game using the game engine Godot 4, chosen for its open-source nature and guaranteed accessibility beyond its lifecycle. A pilot study mapped the ABRAÇO and AMPARO project requirements to Godot's capabilities, confirming technical feasibility. Early efforts focused on implementing continuous integration and automated test suites. Following the pilot, the NeuroMat team designed the software architecture using Domain Driven Design principles, documented via C4 diagrams in line with Godot's recommended practices. The first development iteration produced a publicly available alpha release, aimed at gathering feedback from volunteer researchers for further improvements.

3.3.2 Neuroscience Experiments System

The Neuroscience Experiments System (NES) is a free software to manage data and metadata from neuroscience experiments. It integrates data records from different types such as clinical, electrophysiological, and behavioral. NES is currently being used by the ABRAÇO and AMPARO teams. NES is integrated to the Goalkeeper Game (Section 3.3.1) and to the NeuroMat Open Database (Section 3.3.3). The main functionalities, which include Electrophysiology and Export modules, were improved in the period, and modules that deal with data from machine learning tools are being developed. The NES development team is led by Braghetto.

3.3.3 Neuroscience Experiments Database

The Neuroscience Experiments Database provides an open-access platform for sharing and searching data and metadata from neuroscience experiments. The platform is constituted by a web portal and a REST (Representational State Transfer) API (Application Programming Interface). The web portal was designed to have a user-friendly interface. The REST API is used to feed the open database with experimental data generated by NeuroMat's researchers. Currently, the API intermediates the receiving and retrieving of data from research laboratories that use NES (Section 3.3.2). It can be can easily adapted to receive (or transfer) data from (for) other client systems. The development team of the Neuroscience Experiments Database is led by Braghetto and its source code is available at NeuroMat's GitHub portal.

3.4 Hardware tools

3.4.1 Closed-loop system of robotic stimulator positioning in the brain

The impact of transcranial magnetic stimulation (TMS) on the brain is remarkably precise; deviations of approximately 1 mm in positioning and a few degrees in coil angles can evoke significantly divergent responses. In addition, the patient or volunteer being awake throughout the procedure performs small involuntary movements, even with the head secured on a head strain. If the subject moves during stimulation, the stimulator must be repositioned. As a solution to this problem, robotic arms have been proposed to help position the TMS coil. Robotic positioning also enables the development of new methods for automated motor mapping. However, the combination of TMS and robotic arms is not yet commonly used by the clinical and scientific communities due to three main factors. The first is low portability, that is, the systems are fixed and cannot be transported between rooms and clinics. The second is the high cost of commercial equipment. And the third is that commercial navigation programs are closed systems, making it impossible for new tools to be developed to test different research protocols. A closed-loop system is a set of mechanical or electronic devices that automatically regulates a variable to the desired state, without human interaction. Closed-loop systems are designed to automatically achieve and maintain the desired condition (exit condition), comparing it to its condition at the given moment (real condition).

Since the last report, the team led by Baffa and Ilmoniemi has completed the development of a novel methodology of an autonomous robotized multilocus TMS (mTMS) positioning system. The team has continued research demonstrating that the use of this methodology significantly improves data quality, and the results have been published in top journals and presented in top conferences in the field (see Section 2.3.4).

4 Dissemination report

NeuroMat's dissemination activities have had as a compass point working as a collaborative hub, developing web-2.0 media tools as a means of communicating on-the-go scientific endeavors as well as involving a scientific and broad community around the high-level science that this RIDC has developed. Activities have been envisioned to use innovative means to transform scientific culture, overcoming artificial field boundaries and contributing to foment an integrated and genuinely multidisciplinary approach to the study of the brain. Since 2024, the NeuroMat science dissemination team has been concerned about establishing a process of media legacy around its byproducts and accomplishments, as a means of establishing a lasting memory of the center's role in science research, innovation and dissemination.

NeuroMat's milestone dissemination activities include in the period of interest:

- the *A Matemática do Cérebro* podcast
- the Wikimedia Initiative
- Media Exposure
- Web resources: portal, Facebook page, dissemination blog
- NeuroCineMat
- the Introduction to Science Journalism course
- NeuroMat's science dashboard

4.1 The *A Matemática do Cérebro* podcast

The RIDC NeuroMat launched in August 2019 the podcast "A Matemática do Cérebro" – in Portuguese, Mathematics of the Brain. This resource is available in the most important podcast technologies and also hosted on its own website. The podcast was envisioned by former NeuroMat director Antonio Galves (in memoriam) and NeuroMat associate investigator Eduardo Vicente.

NeuroMat's podcast is aimed at covering three main topics: the model for systems of spiking neurons that the research team developed; the Statistician Brain conjecture; and pertaining institutional aspects of doing research in Brazil. The overall goal is to bring public awareness on work that is being done within the NeuroMat community.

NeuroMat podcasts have released 14 episodes, which have reached 2,131 plays on Spotify in the period of interest for this report. A new season is currently under production, supported by a science journalism fellowship.

4.2 The Wikimedia Initiative

NeuroMat's Wikipedia Initiative, coordinated by NeuroMat's associate investigator João Peschanski, has become a strategic activity at the interface of communication and education. It has been recognized in Brazilian and foreign outlets as a "success case" of the use of Wikipedia and other collaborative projects as a means of scientific dissemination.

This initiative has inspired fellow institutions, in particular the Center for Metropolitan Studies (RIDC CEM) and the University of São Paulo Department of Audiology, Bauru.

Main achievements on Wikipedia have been:

- 154 million content viewers in Wikimedia; and
- 119 million words added to Portuguese Wikipedia and related projects.

Moreover, NeuroMat has been engaged in uploading media files to the open repository Wikimedia Commons. In the period assessed by this report, 79,200 files had been uploaded by the NeuroMat team in this repository. These files have reached 1,744,450 views per month, on average (from 2019 to 2024).

In the period covered by this report, an on-wiki portal for the Wikimedia Initiative has been launched at: https://pt.wikipedia.org/wiki/WikipÃĭdia:GLAM/CEPID_NeuroMat

The control panel of the NeuroMat Wikipedia Initiative is available at: https://outreachdashboard.wmflabs.org/campaigns/neuromat/programs.

The NeuroMat Wikipedia Initiative has been featured in a special paper at Pesquisa FAPESP, available at: https://revistapesquisa.fapesp.br/pesquisadores-e-estudantes-ajudam-a-melhorar-verbetes-da-wikipedia/.

4.3 Media Exposure

Activities from FAPESP'S RIDC NeuroMat were featured in around a hundred external media outlets since its inception in 2013. NeuroMat's media clipping for this year is attached to this report as Annex 4.

Highlights of the period were the series of publications on NeuroMat research papers on the website The Conversation, in Portuguese. These vulgarization pieces were produced in the context of a science journalism fellowship and led to translations in several languages.

4.4 Web resources: portal, Facebook page, dissemination blog

NeuroMat's web portal was launched in early February 2014, and is thought of as the main official reference of the RIDC. It provides robust updates on research, technology transfer and dissemination activities. Publications are in English and Portuguese.

NeuroMat's Facebook page was launched in September 2014 to serve as a reference space for the diverse community that is involved with and interested in Neuromathematics. Since its creation (9/20/2014), the page has reached 4,676 followers, as of August, 2025, including complementary communities led by the ABRAÇO and AMPARO initiatives. Community growth has been organic.

Since April 2016, the NeuroMat dissemination team has maintained a blog on scientific challenges and activities pertaining to science communication, especially relying on web-2.0 platforms. The blog is called "Traço de Ciência".

References are:

- web portal: https://neuromat.numec.prp.usp.br
- Facebook page: https://www.facebook.com/neuromathematics
- ABRAÇO Facebook page: https://www.facebook.com/iniciativaabraco/
- blog: https://difusaoneuromat.wordpress.com

4.5 NeuroCineMat

The NeuroMat dissemination team has fully produced 474 movies, which is then 89 productions since the last report in 2024. A full list is available on the NeuroMat Youtube channel. There has also been continuous streaming of activities on YouTube. A full list is available on:
https://www.youtube.com/user/neuromathematics

This material has been viewed on Youtube and Facebook 45,598 times in the period of interest of this report.

4.6 The Introduction to Science Journalism course

The NeuroMat dissemination team launched in 2021 an Introduction to Science Journalism course to contribute to capacity building of communications professionals who are interested in specializing in science coverage. The course strictly adheres to the curriculum expectations of the Mídia & Ciência call.

The course has been developed under the supervision of NeuroMat's PI Fernando J. Paixão and associate investigator João Peschanski, supported by NeuroMat team members and FAPESP science-journalism fellows.

The course is available freely on Wikiversity:
https://pt.wikiversity.org/wiki/Introdução_ao_Jornalismo_Científico.

This course has become a major asset for FAPESP's journalism fellowships, for NeuroMat and for other scientific projects supported by FAPESP. Since 2017, 36 journalism fellows have been supervised by NeuroMat, most of them have gone through this course. Over 200 students have completed the course over the years.

4.7 NeuroMat's science dashboard

A new institutional academic profile was developed at RIDC NeuroMat, based on Wikidata. Wikidata is a platform inspired by the vision of the Semantic Web, which was designed to allow computers and people to interact over a network. The Semantic Web presents knowledge in a form that is more easily machine-processable, enables data to be linked from a source to any other source, and to be understood by computers. This provides the opportunity to create inference rules and to manage automated reasoning both between people and between machines, so they could perform increasingly sophisticated tasks

The option for a new development was justified due to the disadvantages of the most common platforms, for example, using closed code and having limited functionalities for data visualization and scientometric consultation. In contrast, Wikidata is a collaborative technology, under a free license, which allows queries and visualizations based on inferences made by the users themselves.

The dashboard is available freely on NeuroMat's website:
https://vitrine.numec.prp.usp.br/.

5 Annexes

Annex 1 - NeuroMat global network of scientific, institutional affiliations

Annex 2 - NeuroMat scientific publications

Annex 3 - NeuroMat Scientific Publications: Citations

Annex 4 - NeuroMat's media clipping

Annex 5 - NeuroMat dissemination blog "Traço de Ciência"

Annex 6 - Scientific Missions

Annex 7 - Seminars

Annex 8 - Post-doctoral fellows

Annex 9 - PhD dissertations

Annex 10 - MSc dissertations

Annex 11 - Scientific initiation

Annex 12 - Scientific journalism

Annex 13 - Technical training

Annex 14 - Reports from FAPESP scholarships

- Annex 14.1 – Adriano Jorge Soares Arrigo
- Annex 14.2 – Ana Carolina de Paula Cavalheri
- Annex 14.3 – André Mateus Rodeguero Stefanuto
- Annex 14.4 – Arthur Reis Tabelini

- Annex 14.5 – Bruno Nogueira Galvão Pereira
- Annex 14.6 – Carlo Rondinoni
- Annex 14.6 – Clara Alves Coelho
- Annex 14.7 – Daniela Sano Adathi
- Annex 14.8 – Denilson Feijoeiro Garcia
- Annex 14.9 – Érico Augusto da Silva
- Annex 14.10 – Felipe Orfão Parlato
- Annex 14.11 – Fernando Luis Antunes Sabatini
- Annex 14.12 – Flavio Roberto Rusch
- Annex 14.13 – Gabriel Venas Santos
- Annex 14.14 – Ítalo Ivo Lima Dias Pinto
- Annex 14.15 – Joaquim Castro Penedo de Albuquerque Ferreira
- Annex 14.16 – Juan Mattheus Gil Costa
- Annex 14.17 – Kádmo de Souza Laxa
- Annex 14.18 – Marlon Gomes Calixto
- Annex 14.19 – Milena Satie Miamoto
- Annex 14.20 – Paloma Rodrigues da Silva
- Annex 14.21 – Paulo Roberto Cabral Passos
- Annex 45.22 – Pedro Ribeiro Pinheiro
- Annex 14.23 – Rafael Fernando Gigante
- Annex 14.24 – Rauisa Gonçalves de Macena
- Annex 14.25 – Renan Hiroshi Matsuda
- Annex 14.26 – Simone Vieira da Silva
- Annex 14.27 – Tahnee Valzachi Sugano

- Annex 14.28 – Thaís Cunha Marchetti
- Annex 14.29 – Thiago Takechi Ohno Bezerra
- Annex 14.30 – Vannie Aurin Pavelski da Gama
- Annex 14.31 – Victor Hugo Fernandes de Moraes Faustino