Demetrio Ferro

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SUMMARY I am a computational neuroscientist working at the interface of neural data analysis and theory. My research focuses on how attention, gaze, and internal goals shape decision-making and action. I have developed information-theoretic and spectrally resolved methods to quantify directed, laminar-specific interactions in visual cortical circuits, as well as computational methods showing how gaze and goal states dynamically modulate value encoding in prefrontal brain regions. More recent works focus on theoretical modelling of neural population firing rates for the integration of sensory information and gaze coordination in decision-making. My work combines behavioral and electrophysiological data analyses, advanced statistical signal processing, theoretical modeling to link circuit mechanisms to neural coding and cognitive function across scales.

EDUCATION

PhD in Cognitive, Computational Neuroscience | Diploma supplement
University of Trento, Center for Mind/Brain Sciences, Rovereto, Italy
Istituto Italiano di Tecnologia, Center for Neuroscience and Cognitive Systems, Rovereto, Italy
Defense date: 13 Dec 2019; Supervisor: Prof. Stefano Panzeri.

My PhD project was conducted In collaboration with the experimental lab of Prof. Alexander Thiele (University of Newcastle, UK). I analyzed electrophysiological recordings from visual cortical areas V1 and V4 to study directed causal interactions across cortical layers within and between the two areas. I developed analysis frameworks combining information theory, spectral analysis, and statistical signal processing, introducing autoregressive metrics of spectral and conditional causality based on mutual information. This work enabled a laminar- and frequency-resolved characterization of information flows, showing spectral segregation in feedforward and feedback interactions and strong modulation of neural signals and interactions by visuospatial attention (Ferro et al., *PNAS*, 2021). All computational methods developed during the project were made publicly available, including tools for laminar alignment via current source-density and neural response latency. This work was presented in multiple international conferences (*SfN* 2017, 2019) and in talks invited by peer scientists conducting related studies (at Institut de Neuroscience de la Timone, Marseille, France in 2020; and at University of Amsterdam, Netherlands, in 2024).

M.Sc. degree in Telecommunications Engineering (**"*cum laude*"**) **|** Diploma supplement
Polytechnic of Turin, Dept. of Electronics and Telecommunications (DET), Turin, Italy
Dissertation: 11 Dec 2015; Thesis supervisor: Prof. G. Montorsi (DET),
External supervisors: Prof. C. Berrou and Prof. V. Gripon (Télécom Bretagne, Brest, France).

I acquired solid foundations in stochastic signal processing, system programming, wireless and optical communications, and completed several projects about Information Theory, Coding Theory, Communication systems, Queueing theory, Cryptography, Satellite navigation, Remote sensing. My master degree thesis was conducted through a 6-month internship at Télécom Bretagne (Brest, France), in the lab of Prof. Claude Berrou, pioneer in the field of Information Theory, supervised by Prof. V. Gripon. The thesis consisted in developing a neuro-inspired neural network methods for efficient nearest-neighbor search in high-dimensional data, achieving ~95% reduction in classification complexity and ~77% reduction in image search time (*IJCNN*, 2016).

B.Sc. degree in Computer Engineering | Diploma supplement
University of Salerno, Department of Information Engineering, Electrical Engineering, and Applied Mathematics, Italy; Dissertation: 23 Sept 2013; Supervisors: Prof. S. Marano and Prof. V. Matta

Besides building a background in mathematics, physics, statistics, electronics, digital circuit modeling, programming (C/C++, Assembly, Java, MATLAB, MATLAB GUI, Python, SQL, JavaScript, HTML), computer architecture, logical circuit design, system programming, and operating systems (MS Windows, Linux), as well as in network architectures and protocols (SSH, SFTP, RDP, etc.). My bachelor thesis project was conducted at Co.Ri.Tel (Ericsson) and it focused on analyzing information flows hidden under cover traffic. I developed algorithms to detect covert traffic flows and derived theoretical detectable channel capacity limits for Poisson-distributed traffic. Both results were extended to bidirectional flows and multi-hop routing.

POSITIONS

01/12/2025 – current | Postdoctoral Researcher

Centre de Recerca Matemàtica, Campus Bellaterra, Universitat Autónoma de Barcelona

Postdoctoral researcher n the lab of Prof. Klaus Wimmer. In collaboration with Prof. Alexander Huk (UCLA), my research focuses on the neural mechanisms of perceptual decision-making, combining experimental data from motion direction discrimination tasks with computational modeling. I developed a two-population recurrent network model linking sensory and decision circuits, reproducing adaptive temporal weighting of sensory evidence (primacy, uniform, and recency strategies) observed in behavior and neural activity. This work strengthens my expertise in theoretical modelling, differential network dynamics, and simulation-based inference, providing mechanistic insight into how contextual signals shape decision-making in neural circuits.

11/10/2020 – 30/11/2025 | Postdoctoral Researcher

Center for Brain and Cognition, Deptartment of Engineering, Pompeu Fabra University (Barcelona, Spain)

In the lab of Prof. Rubén Moreno-Bote, I investigated value-based decision-making and the influence of internal goals on neural evaluation processes. In collaboration with Prof. Benjamin Hayden (Baylor College of Medicine, USA), I developed a framework to study how directing gaze toward the spatial location of reward-associated cues selectively modulates their neural value representations in orbitofrontal cortex, both during their presentation and at later blank screen delays before choice, and that modulation strength is choice-predictive (*Nature Communications*, 2024). Furthermore, I investigated the role of goal-directed influences on decision-making. Using a token-based task, I found that subjects made faster and more accurate decisions as the accumulation of tokens brought them closer to a jackpot reward. By modeling subjective value through a utility function inspired by Prospect Theory, I characterized a reference-shifting strategy whereby value is evaluated as potential gain or loss depending on reward proximity. This study showed that dorsal anterior cingulate cortex enhances the neural encoding of potential gains relative to losses, through the recruitment of larger encoding populations, and that neural value encoding weights are tightly linked to choice behavior (*Nature Communications*, 2026). Through collaboration with Prof. Tianming Yang (NYU-ECNU, Shanghai), I developed a closed-loop computational model linking visual sampling and decision formation (*CCN* 2025), which I am currently integrating with experimental data. In parallel, I collaborate with Prof. Sonja Grün (Jülich, Germany) and Dr. Thomas Brochier (Marseille, France) on context-dependent neural encoding, investigating how individual motor actions recruit specialized neural representations across overlapping action sequences. Overall, my postdoctoral work broadened my expertise across attention, intention, decision, and action, combining neural modeling with gating mechanisms to explain how functional states shape sensory and motor computations.

01/11/2019 – 31/08/2020 | Research assistant at the Center for Neuroscience and Cognitive Systems, Istituto Italiano di Tecnologia (Rovereto, Italy)

During this period, I consolidated and extended my PhD research, leveraging the richness of the experimental dataset to pursue additional analyses and broaden the scope of investigation. This work contributed to strengthen my profile and supported the completion and dissemination of my PhD work. This time overlapped with COVID-19 pandemic, which delayed the start of my postdoc.

My tasks focused on getting all the materials and methods produced during my PhD ready for open-access publication in my own repositories (https://gin.g-node.org/56fe) and to work on manuscript writing and reviews, later accepted for publication (Ferro et al., *PNAS* 2021).

01/11/2016 – 31/10/2019 | PhD Candidate at the Center for Mind/Brain Sciences, University of Trento (Rovereto, Italy)

Branching from engineering studies, I pursued a PhD project in the computational lab of Prof. Stefano Panzeri in collaboratin with the experimental lab of Prof. Alexander Thiele in Newcastle, UK. We faced multiple experimental and theoretical challenges but exploited our knowledge to combine the efforts in developing robust and efficient tools for achieving the quality assessment and anatomical alignment of high-resolution laminar neural data of our interest. The initial part of this project expanded broadly due to the complexity of the methods but enriched my background and contributed to my current knowledge of primate neurophysiology. The work was published (Ferro, IRIS 2019; Ferro et al., PNAS 2021) along with multiple repositories for laminar alignment, latency estimation and directed information flows detection (https://gin.g-node.org/56Fe).

01/04/2016 – 30/10/2016 | Internship at the Center for Neuroscience and Cognitive Systems, Istituto Italiano di Tecnologia (Rovereto, Italy)

I embarked on my neuroscience journey, thanks to the support of Prof. Stefano Panzeri and his research group. This time was particularly fruitful for me to approach research life and to acquire study certificates for highly relevant methods (Machine Learning by Prof. Andrew Ng) and the basis of neuroanatomy and neural functions (Medical Neuroscience by Prof. Leonard E. White).

01/04/2015 – 30/09/2015 | Master thesis at Institut Mines-Télécom (Brest, France)

I developed a novel solution for nearest neighbor search, a common task in computer vision and pattern recognition. The method combined vector quantization with neural networks to outperform state-of-the-art in efficiency and scalability, achieving about 95% complexity reduction in image classification, and 77% for image search. Presented and published in *IJCNN*, Vancouver 2016.

TEACHING MENTORING

Teaching

I taught Scientific Communication (3 ECTS) in the bachelor's degree of Biomedical Engineering. Modules: I. Scientific writing and source referencing; II. Public speech evaluation and presentation delivery; III. Reviewing essays of peer students and proposing alternative versions fitting instructed guidelines; IV. Reproducibility and transparency of publication, the licenses for software and data, repositories and digital object identifiers. Students were evaluated by a weighted sum of four assignments, one for each module. For module II, each student was asked to prepare an individual presentation and evaluated individually with point-by-point feedback. For this activity, I received positive feedback evaluations by students.

I chaired the committee for bachelor's degree (Treballs de fi de Grau, TFG), in 2024 and in 2025, and for master's degree (Treballs de fi de Masters, TFM) in the Neuroscience panel in 2022.

Mentoring

I supervised 2 bachelors theses (6 months each) and 2 internship students (3 months each).

The first thesis student (2020–2021) analyzed spiking activity to study the neural encoding of task-related cognitive variables in a decision-making task, contributing to Ferro et al, CCN (2023).

The second thesis student (2024) worked on Allen Institute's "Visual Behavior Neuropixels" data, implementing spectral and laminar analyses to classify signals by cortical layers and task conditions, to be integrated in my current research framework for publication planned in future work. The student later joined a top-tier computer science master program in Japan.

Internship students worked with publicly available data from the Allen Brain Institute. The first student characterized covariability and mutual information across neural populations, while the second student analyzed response latencies across laminar depths and task conditions. The first student continued into a prestigious computer science program, and the second, inspired by the internship, pursued a thesis on brain networks and enrolled in a competitive Computational Neuroscience master at the ETH in Zürich, which I gladly supported via recommendation letter.

RESEARCH PROJECTS

Neural network mechanisms underlying perceptual decision-making (2025 – ongoing)
Collaboration with the lab of Prof. Alex Huk at UCLA, in the USA. Neural network models of sensory and decision-formation neural populations for adaptive temporal-weighting of sensory information (recency, primacy) in a perceptual motion discrimination task (under development).

Gaze2Decision (2024 – ongoing)
Collaboration with the experimental lab of Dr. Tianming Yang at the NYU-ECNU in Shanghai, China. Closed-loop circuit modelling of two-paired mutually inhibiting networks of neural units for the interaction between gaze direction and decision formation (Ferro et al., *CCN* 2025).

Vision4Action (2024 – ongoing)
Joint venture with the lab of Prof. Sonja Grün (Institute for Advanced Simulations, Jülich, Germany) and the experimental lab of Dr. Thomas Brochier (Institut de Neuroscience de la Timone, Marseille, France). Analysis of neural data collected during a hand landing task for the coordination of visual and motor functions (under development).

Hayden Lab (2021 – ongoing)
Collaboration with the experimental research lab of Prof. Benjamin Hayden at the Baylor College of Medicine, Houston, USA. Analysis of the neural encoding of reward-based values and the role of gaze position in decision-making tasks (*CCN* 2023; *Nature Communications* 2024; *CCN* 2025; *Nature Communications* 2026).

Human Brain Project (HBP), Co-funded by the EU (2022-2023)
Consortium of Research on Decision-Making (CoReDeM), bringing together theoretical (PIs: R. Moreno-Bote and I. Cos at Univ. Pompeu Fabra, Barcelona; A. Destexhe from Centre National de la Recherche Scientifique Paris Saclay) and experimental research groups (PIs: S. Ferraina, Sapienza University, Rome, and T. Theys, Leuven, Belgium). [Report: SGA3 M42; EBRAINS].

The effects of attention on laminar interactions (2017 – 2021)
Collaboration with the experimental group of Prof. A. Thiele at the University of Newcastle, UK. Analysis of laminar-specific effects of attention on inter- and intra-areal directed information flows within brain areas V1 and V4 (Ferro, *IRIS* 2019; Ferro et al., *PNAS* 2021).

PUBLICATIONS

Peer-reviewed journal articles

Nature Communications 2026
"Accumulation of virtual tokens towards a jackpot reward enhances performance and value encoding in dorsal anterior cingulate cortex"
D. Ferro*, H. Azab, B. Y. Hayden and R. Moreno Bote
Nature Communications, 17:2537, 2026; 10.1038/s41467-026-70423-1; ***Corresponding author**

In proximity of large rewards, subjects perform choices faster and more accurately, reflecting a fundamental shift in their evaluation strategy that is not readily explained by speed versus accuracy trade-off. The evaluation of alternative options is referenced to a cumulative token count leading to a large jackpot reward. Neural activity in dorsal anterior cingulate cortex tracked token reference shifts, revealing a neural basis for reference-dependent evaluation in decision-making.

Nature Communications 2024
"Gaze-centered gating, reactivation, and reevaluation of economic value in orbitofrontal cortex"
D. Ferro*, T. Cash-Padgett, M. Zhe-Wang, B. Y. Hayden, R. Moreno Bote,
Nature Communications, 15:6163, 2024; 10.1038/s41467-024-50214-2;
***Corresponding author**; Citations: 13 (Scholar, March. 2026).

Gaze behavior strongly influences decision-making during economic choices. Looking at the screen locations where options are or were presented activates or reactivates their value encoding in orbitofrontal cortex. This reactivation correlates with upcoming choices, indicating that gaze plays an active role in reevaluating internal representations.

PNAS 2021
"Directed information exchange between cortical layers in macaque V1 and V4 and its modulation by selective attention"
D. Ferro, J. van Kempen, M. Boyd, S. Panzeri, A. Thiele
Proceedings of the National Academy of Sciences (PNAS), 118 (12), e2022097118, 2021
10.1073/pnas.2022097118; Citations: 62 (Scholar, March 2026).

This work maps how visual and attentional information propagate within and between cortical areas V1 and V4 at laminar resolution. Results show interlaminar and interareal circuit motifs, attention-related shift in the high-frequency band spectral peak and increased high-frequency power. Attention reduced local communication within V1 but enhanced both feedforward and feedback signaling across areas, especially in the high-frequency bands.

Peer-reviewed Conference Proceedings

CCN 2025
"A closed-loop model for the coordination of gaze control and decision-making"
D. Ferro, T. Yang and R. Moreno-Bote,
Cognitive, Computational Neuroscience (CCN), 2025; PDF

This work introduces a closed-loop model linking gaze behavior with value-based decision-making. Visual input drives competing decision populations, which guide gaze shifts that feed back into the decision process. Simulations capture key behavioral dynamics, offering a framework to study how gaze shapes neural and decision-related activity.

CCN 2025
"Decision-making reference point biases in the dorsal anterior cingulate cortex"
D. Ferro, H. Azab, B. Y. Hayden, R. Moreno-Bote,
Cognitive, Computational Neuroscience (CCN) 2025; PDF

This study examined how reference-point bias affects probabilistic decision-making in a behavioral task where virtual tokens indicate jackpot achievement odds. As token counts increased, participants made quicker, more accurate decisions, reflecting sensitivity to current reward status. Performance also improved in easier trials with more salient, high-value options, suggesting reference-dependent biases influence behavior beyond the standard speed-accuracy tradeoff.

CCN 2023
"The role of gaze for value encoding and recollection in orbitofrontal cortex"
D. Ferro, A. Rifé-Mata, T. Cash-Padgett, M. Zhe-Wang, B. Hayden, R. Moreno-Bote
Cognitive, Computational Neuroscience (CCN), 2023; 10.32470/CCN.2023.1122-0;

Gaze is drawn more to valuable options and predicts choice outcomes. Orbitofrontal cortex activity enhances the encoding for fixated locations and suppression of alternatives. These findings suggest that gaze supports internal deliberation by modulating neural value signals.

IJCNN 2016
"Nearest neighbour search using binary neural networks"
D. Ferro, V. Gripon, X. Jiang,
International Joint Conference on Neural Networks (IJCNN), IEEE, 5106-5112, 2016
10.1109/IJCNN.2016.7727873; Citations: 11 (Scholar, Oct. 2025)

Nearest neighbor search is a common task in computer vision and pattern recognition whose complexity grows with data dimensionality. The method proposed here combines Product Quantization with neural networks to outperform state-of-the-art methods both in efficiency and scalability, achieving about 95% reduction in classification on MNIST dataset, and 77% reduction in nearest neighbor search on 1M image descriptors dataset (TEXMEX 1M, INRIA, Rennes, France).

PEER REVIEWS

I have contributed multiple times to reviewing the work of peer authors, indicating scientific maturity and of the reliability of my academic achievements. As of March 2026, I contributed to:
1 peer reviews for Nature Neuroscience (verifiable at ORCID),
1 peer reviews for Nature Communications (verifiable at ORCID),
7 peer reviews for PLOS Computational Biology (verifiable at Web of Science),
1 peer review for Qeios (verifiable at Web of Science),
10 abstracts reviewed for Cosyne 2026, 3+ abstracts reviewed for CCN 2023 and CCN 2025.

EVENTS ORGANIZATION

In the last years, I have taken part in and organized multiple social events within the network of scientists and neuroscientists in Barcelona. I joined and actively participated in the Barcelona Computational, Cognitive and Systems Neuroscience community. I participated in annual conferences, seminars, presented my work multiple times, and organized **two retreats for the whole community** (in 2022 and in 2024) including members at all career stages (~60 people). The retreats consisted of 3 days of reunions of the network with fully immersive scientific and community-related discussions, and great opportunities for mutual exchange and networking.

During my PhD, (March 2017 – April 2018) I organized a year-long series of weekly seminars inviting local and visiting scientists interested in sharing and promoting their research, highly relevant for the local community of the Center for Mind/Brain Sciences, Rovereto, Italy.

In addition, I have established connection with the Societat Catalana de Biologia (SCB) and the Centre de Recerca Matematica (CRM), where I met peer members with whom I enjoyed great conversations. Attracted by the "Mes Cajal" events organized by the SCB, I also started to interact with colleagues involved in the research fields of biotechnology, oncology and cell cultures. Through their invitation, I joined the "PostDoc Day in Biomedical research", co-organized by SCB, and extended invitation to neuroscience colleagues, proudly connecting people across fields.

Similarly, during the last years I interacted on many occasions with CRM colleagues, before joining the center as a postdoc in December 2025, through their series of "Neurochats", bringing together pre- and post-doctoral researchers in periodic meetings where I also had the chance to present in May 2025. In addition, I was invited to present my work to the hub of "Computational and Mathematical Neuroscience", invited by Dr. A. Hyafil.

PUBLIC OUTREACH

Since the beginning of my career, I have been committed to scientific communication, with the clear idea that scientific discoveries lose their impact if they have poor outreach or if they are only accessible by a minority of the population. I have spent many years of my training in studying open access policies, developing open-source software, and learning how to properly publish data and code in a transparent, reproducible way, as by the standards of findability, accessibility, interoperability, and reusability (FAIR). All my research is published on open access journals, and all the data and code are publicly available on my repository page.

I have enthusiastically participated in public outreach events (European Researcher's Night, Festa de la Ciencia and Pint of Science) in Barcelona, and previously, in France and in Italy.

I have published informative articles about my research on important outlets like EurekAlert (AAAS), Medical Xpress (Science X), Bioengineer.org and News-Medical Life Sciences.

INTERNATIONAL VISIBILITY

Contributed Presentations in the form of posters (p) or talks (t). Among the most relevant:

- (p) Systems in Action, March 2026 (Alicante, Spain).
- (p) Cognitive, Computational Neuroscience, August 2025 (Amsterdam, Netherlands).
- (t) Citizen Art-Science Engagement Strategies (CASES), July 2025 (Barcelona, Spain).
- (p, t) International Conference on Thinking, June 2024 (Milan, Italy).
- (p) Cognitive, Computational Neuroscience, August 2023 (Oxford, UK).
- (p) Human Brain Project Summit, March 2023 (Marseille, France).
- (p) Barcelona Cognitive, Computational Systems Neuroscience, May 2022 (Barcelona, Spain).
- (p) Cognitive Systems Neuroscience (Cosyne), March 2022 (Lisbon, Portugal).
- (t) Spanish Network for the Interaction between Computational and Cognitive Neuroscience ($SINC^2$), Nov. 2021 (Lleida, Spain).
- (p) Spanish Society for Neuroscience (SENC), Nov. 2021 (Lleida, Spain).
- (p) Barcelona Cognitive, Computational Systems Neuroscience, July 2021 (Spain).
- (p) Annual Meeting of the Society for Neuroscience (SfN), 2019 (Chicago, USA).
- (p) PhD Doctoral student Day at the University of Trento, 2019 (Rovereto, Italy).
- (p) Ten Years of Mind/Brain Sciences, University of Trento, 2017 (Rovereto, Italy).
- (p) Annual Meeting of the Society for Neuroscience (SfN), 2017 (Washington, USA).

You can find an exhaustive, updated list of all conferences on my website.

Invited talks as guest speaker in multiple occasions (~1x year), presenting my research findings and disseminating methods I developed and made publicly available to peer scientists in the field.

- 2025 Centre de Recerca Matematica (Barcelona, Spain)
- 2024 Universiteit van Amsterdam (Amsterdam, Netherlands)
- 2023 Center for Mind/Brain Sciences (Rovereto, Italy)
- 2023 Human Brain Project, Work Package 2 Meeting (Barcelona, Spain)
- 2022 Multi-Scale Brain Function India-Italy Network of Excellence (Varenna, Italy)
- 2020 Institut de Neuroscience de la Timone (Marseille, France)

AWARDS

Funding

I redacted, submitted, and was awarded a research proposal fully conceived by me on “gaze-centered decision making,” securing research funding for two years of my postdoctoral activities in 2022 from the Bial Foundation (PT/FB/BL-2022-106). I also curated the final report.

OTHER ACTIVITIES

Citizen Science

I actively participate in the Citizen Art-Science Engagement Strategies (CASES) network, operating within the EUTOPIA Impact and Dissemination programme at the Universitat Pompeu Fabra in Barcelona, a collaborative alliance of like-minded European universities. The initiatives include collective environmental data sampling, informational meetings on scientific reports. I have contributed by disseminating my research on attention, decision-making and implications for executive functions and impairments to network members in 2025 and to school students in 2026.