May 2024 | Issue n° 4

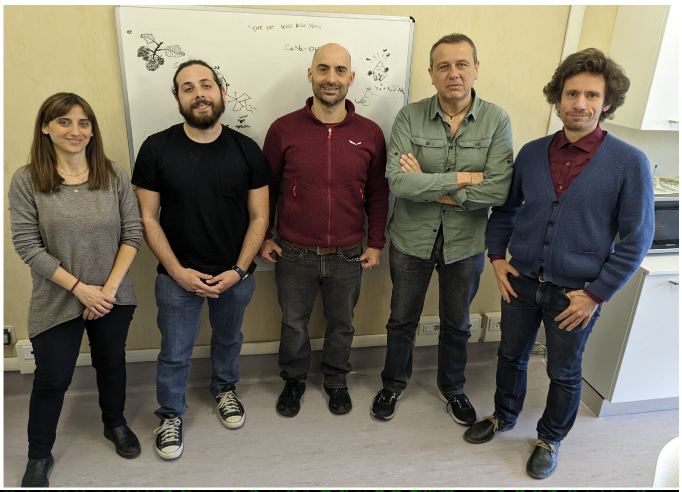
www.experience-project.eu

eXperience in the second period

Dear Colleagues,

I'm excited to share the transformative outcomes of our UniTV team's research in brain decoding for the EXPERIENCE project, which merges virtual reality with social interactions. We showed that brain decoding can be generalized across different subjects using a simple alignment technique. By training a model on one subject's fMRI data and applying it successfully to another, we established that our models can adapt to varying neurophysiological data, crucial for creating personalized VR environments. Significantly, we also integrated brain decoding with multimodal outputs, developing methods to decode brain activity into both visual and textual forms. This is vital for generating VR content that aligns with the complexities of human cognition, capturing both visual and narrative user experiences. Additionally, we enhanced our decoding capabilities by merging vision and language processing techniques. With advanced AI methods, we've improved the accuracy and diversity of reconstructing images and text from fMRI data, enabling the creation of VR environments that are both realistic and narratively rich. Our team pioneered a method to decode visual stimuli from EEG signals, simplifying the production of personalized VR scenarios and broadening their use in social platforms. Moreover, we advanced brain captioning techniques, setting new standards in representing human thoughts, crucial for VR environments that replicate and convey cognitive and emotional states. These advancements contribute to a comprehensive system where VR environments are dynamically crafted from neurophysiological inputs, potentially revolutionizing social interactions, therapeutic interventions, and personal entertainment in Europe. of the next generation of extended reality applications.

The PI for University of Rome Tor vergata
Nicola Toschi



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Contact: simona.moschini@unipi.it

European Union's Horizon 2020 research and innovation programme under grant agreement No. 101017727

eXperience PROJECT INTER VIEWS

Name: Nicola
Surname: Toschi
Title: Full Professor
Affiliation: University of Rome Tor Vergata – *Medical Physics Section*

TOR VERGATA
UNIVERSITÀ DEGLI STUDI DI ROMA
Sezione di Fisica Medica

1. Favorite areas of interest and research
Neuroimaging, generative AI, Signal Processing, neurotechnology, medical physics, nanointerfaces.

2. Can you mention some of the most promising research directions in the neuroimaging field?
Brain encoding and decoding for the future of BCIs.

3. Which innovation influenced mostly your scientific world in the last 10-20 years?

Ultra high-field magnetic resonance imaging (MRI), nanosized biomaterials, and AI. Ultra high-field MRI systems, with magnetic fields of 7 Tesla or higher, significantly improve MRI imaging resolution and speed, enabling detailed visualization of brain structures. This allows researchers to explore previously indiscernible microstructures and neural networks, crucial for diagnosing and understanding neurological diseases like multiple sclerosis, Alzheimer's, and schizophrenia. Recent advancements in nanosized biomaterials have led to the creation of neuromodulating nanosized biointerfaces that interact with neuronal cells to influence activity at the nanoscale. These biomaterials, targetable to specific neuronal receptors or ion channels, facilitate precise neural pathway modulation or can be used in electrical stimulation for brain-machine interfaces and deep brain therapies. Complementing these, microsized implantable neurotechnologies, like microelectrode arrays and microfluidic devices, offer precise monitoring and manipulation of neural activity and drug delivery, significantly enhancing neurotherapeutic precision and efficacy. The fusion of AI and neuroscience, or 'neuro-AI,' enhances our ability to interpret complex brain data through machine learning and deep learning algorithms. These algorithms excel at identifying subtle patterns in brain imaging data, improving brain function models, and enhancing the accuracy of diagnosing and predicting neurological conditions. AI also customizes neurorehabilitation therapies, adapting treatments in real-time to patient progress.

4. What was your motivation to become a researcher?
Intellectual challenge of solving complex problems

5. eXperience is....
My research has focused into neuroimaging and its applications in understanding neurological states and improving therapies. The EXPERIENCE project represents an advancement in this area, integrating virtual reality (VR) and artificial intelligence (AI) to enhance social interactions and therapeutic approaches. In studies like those on neuroinflammatory mechanisms in Alzheimer's and precision medicine in neurology, we have used neuroimaging to understand and manipulate neural pathways. EXPERIENCE builds on this by using VR environments that reflect individual neurophysiological data to evoke specific psychological responses, aligning with my interest in how environments influence neurobiology. For example, our work on the neuromodulatory effects of transcranial magnetic stimulation could inform VR settings designed to modulate neurological states or rehabilitate cognitive functions, using AI to adapt environments based on user interaction. This capability could transform treatments for psychiatric disorders, offering controlled settings to manage traumatic memories or anxiety This opens new avenues for mental health management and broadens our understanding of the neural bases of emotion and cognition, also enhancing fields like e-learning and neuroeconomics by studying immersive experiences and decision-making processes. Thus, EXPERIENCE is not just an extension of my research but expands the impact of neuroscience and technology across various domains.

1. My favorite non-scienfic book, musician and movie...
Book: *How to Walk*
Musician: *Keith Jarrett*
Movie: *Killing Zoe*

2.I like to spend my free-me / vacation in....
Deep seawater

3. My favorite course (meal)...
Chocolate

4. The character trait I really dislike....
Asking inappropriate questions

5. A best sentence...
"The word "depressed" is spoken phonetically as "deep rest". We can view depression not as a mental illness, but on a deeper level, as a profound, and very misunderstood, state of deep rest, entered into when we are completely exhausted by the weight of our own identity."
— Jeff Foster

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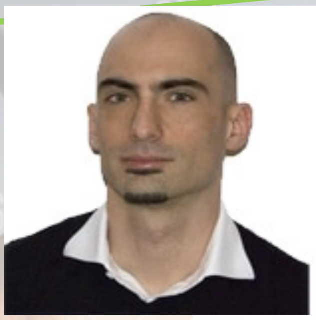
PEOPLE

eXperience PROJECT



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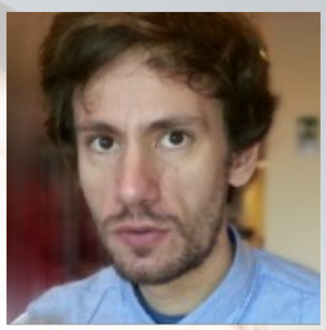
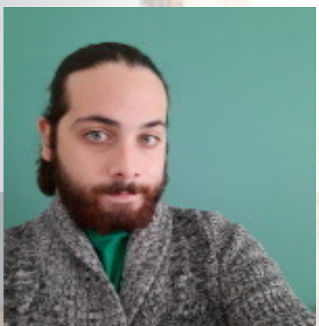


Nicola Toschi

Nicola Toschi is a Full Professor in Medical Physics at the University of Rome “Tor Vergata”. His research is interdisciplinary, with a focus on scientific and technological solutions for the deployment of advanced physical and mathematical techniques in order to extract quantitative information of investigative, diagnostic and prognostic value in a clinical context. He is a senior member of the IEEE society, an active member of ISMRM and OHBM, a founding member of the Alzheimer’s Precision Medicine Initiative (AMPI) a member of the Technical Committee on Cardiopulmonary Systems.
Participation in eXperience WPs: WP2, WP3

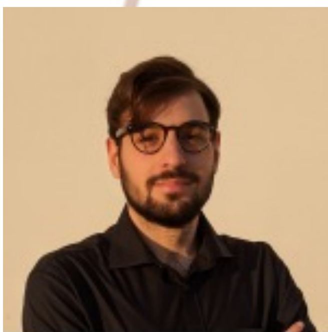
Andrea Duggento

Andrea Duggento, Associate Professor of Medical Physics at UNITOV, holds bachelor’s and master’s degrees in Theoretical Physics from the University of Pisa and a PhD in Physics from Lancaster University. With a Medical Physics Degree from the University of Rome “Tor Vergata”, Andrea’s research focuses on nonlinear dynamical systems, statistical analysis, and information processes in biological networks.
Participation in eXperience WPs: WP2, WP3



Matteo Ferrante

Matteo Ferrante is a Ph.D. candidate at the National AI Ph.D. – Health and Life Sciences program, studying neuromorphic architectures and generative therapeutic “telepathy.” He has degrees in Physics and Biomedical Physics from the University of Pavia. His interests lie in artificial intelligence, precision medicine, and neuroscience.
His Ph.D. project focuses on decoding visual stimuli in the brain and generating activation maps using mappings between latent spaces of the brain and artificial neural networks.
Participation in eXperience WPs: WP2, WP3



Tommaso Boccato

Tommaso Boccato is a student in the Italian National Ph.D. Program in Artificial Intelligence at the Tor Vergata Medical Physics Section.
He holds a bachelor’s degree in Information Engineering and a master’s degree in ICT, both from the University of Padova. His interests include neural networks, deep learning, network science, and computer vision. Tommaso’s current research focuses on neuromorphic architectures. *Participation in eXperience WPs: WP2, WP3*

Tullia Di Corcia

Tullia Di Corcia currently serves as a Project Manager for the Medical Physics unit, overseeing EU grants.
She is managing several EU-funded projects, including H2020 and Horizon Europe, actively participating in all stages of the research project life cycle.
She also contributes to the communication and dissemination of research results.

Antonio Canichella

Antonio Canichella is part of the technical and support staff. He is skilled in electronic measurements, in physiological signal recording and analysis from medical equipments and transducers. Besides, he is an expert in waveform analysis software and analysis and development of websites.
Participation in eXperience WPs: WP2, WP3

European Union’s Horizon 2020 research and innovation programme under grant agreement No. 101017727

Building transformers from neurons and astrocytes

Glial cells account for between 50% and 90% of all human brain cells, and serve a variety of important developmental, structural, and metabolic functions. Recent experimental efforts suggest that astrocytes, a type of glial cell, are also directly involved in core cognitive processes such as learning and memory. While it is well established that astrocytes and neurons are connected to one another in feedback loops across many timescales and spatial scales, there is a gap in understanding the computational role of neuron–astrocyte interactions. To help bridge this gap, we draw on recent advances in AI and astrocyte imaging technology. In particular, we show that neuron–astrocyte networks can naturally perform the core computation of a Transformer, a particularly successful type of AI architecture. In doing so, we provide a concrete, normative, and experimentally testable account of neuron–astrocyte communication. Because Transformers are so successful across a wide variety of task domains, such as language, vision, and audition, our analysis may help explain the ubiquity, flexibility, and power of the brain's neuron–astrocyte networks.

Kozachkov, Leo, Ksenia V. Kastanenka, and Dmitry Krotov. "Building transformers from neurons and astrocytes." Proceedings of the National Academy of Sciences 120.34 (2023): e2219150120.

KAN: Kolmogorov-Arnold Networks

Inspired by the Kolmogorov-Arnold representation theorem, we propose Kolmogorov-Arnold Networks (KANs) as promising alternatives to Multi-Layer Perceptrons (MLPs). While MLPs have fixed activation functions on nodes ("neurons"), KANs have learnable activation functions on edges ("weights"). KANs have no linear weights at all -- every weight parameter is replaced by a univariate function parametrized as a spline. We show that this seemingly simple change makes KANs outperform MLPs in terms of accuracy and interpretability. For accuracy, much smaller KANs can achieve comparable or better accuracy than much larger MLPs in data fitting and PDE solving. Theoretically and empirically, KANs possess faster neural scaling laws than MLPs. For interpretability, KANs can be intuitively visualized and can easily interact with human users. Through two examples in mathematics and physics, KANs are shown to be useful collaborators helping scientists (re)discover mathematical and physical laws. In summary, KANs are promising alternatives for MLPs, opening opportunities for further improving today's deep learning models which rely heavily on MLPs.

Liu, Ziming, Yixuan Wang, Sachin Vaidya, Fabian Ruehle, James Halverson, Marin Soljačić, Thomas Y. Hou, and Max Tegmark. "KAN: Kolmogorov-Arnold Networks." arXiv preprint arXiv:2404.19756 (2024).

European Union's Horizon 2020 research and innovation programme under grant agreement No. 101017727

FLASH NEWS

eXperience PROJECT

KANSEI OUT OF SCANNER DATA COLLECTION COMPLETE

With our colleagues at UPV, we are aiming at establishing a correlation between the spatial properties of 3D virtual environments (3DVE) and the cognitive/emotional states (CES) they evoke. This interdisciplinary study utilizes Kansei engineering methodology to operationalize the complex, multidimensional construct of cognitive/emotional states by linking them to specific spatial attributes of 3DVEs through semantic scales. Initially, a broad set of adjectives describing virtual environments was collected and refined by experts to form a reduced set representing core semantic dimensions. This set was then used to generate samples of virtual environments, which were assessed at UNITOV by participants using functional magnetic resonance imaging (fMRI) to establish a 'Kansei signature.' This signature identifies the neural correlates of the subjective experience, measured against the semantic scales in controlled, varied virtual settings. The methodology encompasses identifying and refining a semantic universe for virtual environments, generating representative samples of these environments, and then empirically assessing them with fMRI to map the spatial properties to emotional/cognitive responses. This complex process aims to augment the recording and transmission of experiences through AI.

Latest EXPERIENCE papers from UNITOV!

Ferrante, M., Boccato, T., & Toschi, N. (2024). Towards neural foundation models for vision: Aligning EEG, MEG and fMRI representations to perform decoding, encoding and modality conversion. In *ICLR 2024 Workshop on Representational Alignment*.

Ferrante, M., Boccato, T., Ozcelik, F., VanRullen, R., & Toschi, N. (2024). Through their eyes: multi-subject Brain Decoding with simple alignment techniques. *Imaging Neuroscience*.

Boccato, T., Ferrante, M., Duggento, A., & Toschi, N. (2024). 4Ward: A relayering strategy for efficient training of arbitrarily complex directed acyclic graphs. *Neurocomputing*, *568*, 127058.

European Union's Horizon 2020 research and innovation programme under grant agreement No. 101017727

Last&Next Events

eXperience
PROJECT

NEURAL INFORMATION PROCESSING SYSTEMS

AAAI-24 / IAAI-24 / EAAI-24

ICLR
International Conference On Learning Representations

IEEE EMBS INTERNATIONAL CONFERENCE ON
DATA SCIENCE AND ENGINEERING IN HEALTHCARE, MEDICINE, & BIOLOGY
7-9 DECEMBER 2023 • MALTA

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