BRAID: Brains AI and Data! Workshop

Wednesday 22 January, 09:30-16:30

Watershed, 1 Canon's Rd, Bristol, BS1 5TX

Event programme

Elizabeth Blackwell Institute

University of Bristol Jean Golding Institute

09.30: Welcome

Conor Houghton, **Associate Professor in Computer Science, School of Engineering Mathematics and Technology, University of Bristol**

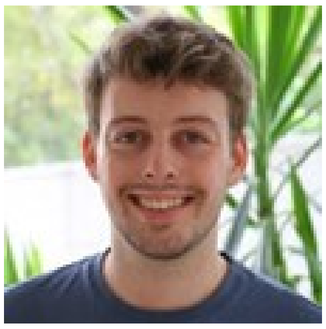
09.35: Analysing brain activity and behaviour

Emma Cahill, Lecturer, School of Physiology, Pharmacology & Neuroscience, University of Bristol

AI for mental health: Rise of ChatGPTherapy?

Digital therapeutics are increasingly regarded as viable options to support mental health and well being. Many were originally developed for use by a therapist employing specialist equipment. In this talk, I will describe for example how virtual reality (VR) versions of cognitive behavioural therapy for Post-traumatic Stress Disorder (PTSD) have been widely tested; and overview our recent collaborative project to develop a VR training tool to educate about PTSD symptoms.

More recently and more frequently these digital therapeutics tools are developed as accessible mobile applications. I will outline another collaboration with a Bristol-based organisation, Spicey Minds, where we examine the capacity of ChatBots to recognise the overlap of diagnostic symptoms across different psychiatric conditions using an AI therapist and AI clients.



Tom Maullin-Sapey, Lecturer in Statistics, School of Mathematics, University of Bristol

Confidence Regions for Conjunction Analysis of fMRI data

Traditionally, uncertainty estimation in fMRI inference has primarily been concerned with how signal magnitude at each specific voxel varies under repeated sampling. As such, very little attention is given to the variability in signal location. Understanding such spatial variability is crucial, however, especially when images are to be compared to one another, and regions of overlapping signal are of functional interest.

In this talk, I will describe how Confidence Regions (CRs) may be used to characterize the spatial uncertainty of the intersection, and union, of regions of activation obtained under different study conditions. Such combinations are of natural interest as they directly correspond to questions of the form "Where was brain activity observed *under all study conditions*?" and "Where was brain activity observed for *at least one study condition*?". I shall first illustrate the general method, and then provide a brief example of its usage in assessing spatial uncertainty for a working memory task.

Seán Froudist-Walsh, Lecturer, School of Engineering Mathematics and Technology, University of Bristol

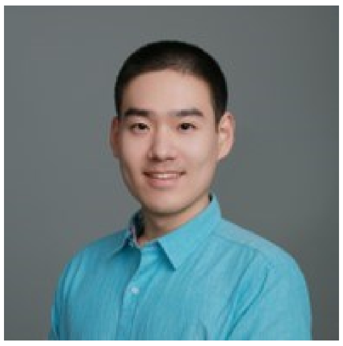
Circuit and cortex-wide mechanisms of psilocybin on cortical dynamics and perception

Psilocybin is a psychedelic drug that alters conscious perception by acting on the receptors for serotonin in the brain. I will speak about our progress towards understanding how psilocybin affects brain-wide network activity and alters perception. This will touch on our analyses of cortex-wide neuroanatomy, local circuit physiology and multi-scale neural network modelling of perception and cognition.

10.15 Panel discussion and questions

Chair: Tamara Boto, Senior Lecturer in Neuroscience, School of Physiology, Pharmacology & Neuroscience

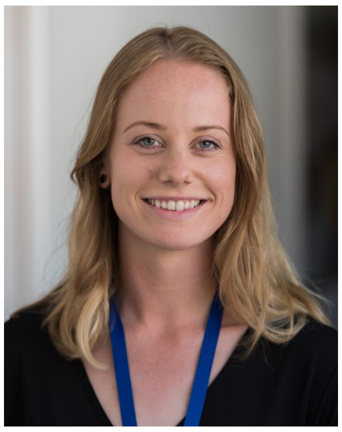
10.35: Disorders



Qiang Liu, Lecturer in Data Science, School of Engineering Mathematics and Technology, University of Bristol

AI-based cell screening for Alzheimer's disease

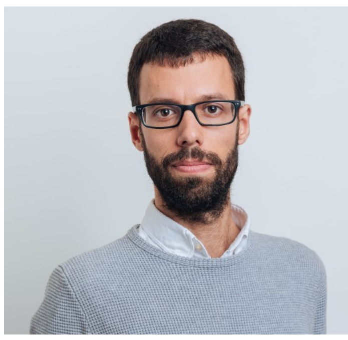
Alzheimer's disease remains one of the most pressing challenges in biomedical research, requiring innovative approaches to unravel its cellular mechanisms and therapeutic opportunities. This talk will explore the development and application of AI-based methodologies for screening Alzheimer's disease-related cellular phenotypes.



Holly Fraser, Senior Research Associate in Immunopsychiatry, Bristol Medical School, University of Bristol

Identifying inflammation related subgroups of psychopathology using machine learning

Mapping heterogeneity in depression and other mood disorders is a key challenge in psychiatric research. What do people who share a diagnostic label have in common with each other? What differentiates them? Hidden amongst a clinical population of interest could be defined subgroups that have a unique combination of risk factors, specific symptoms, illness histories, and response to treatment, as well as differing mechanistic trajectories to their disease state. One potential mechanism which confers vulnerability to mental health problems is low-grade, systemic inflammation. Inflammation is shown to be specifically associated with both somatic symptom profiles in depression and negative symptomatology in schizophrenia and psychosis, rendering it a potential transdiagnostic risk factor for psychiatric disease. This work aims to identify psychiatric subgroups with shared immunological markers and characterise these subgroups with regards to relevant demographic and clinical characteristics. To explore stratification we are applying a suite of clustering algorithms and other data decomposition methods to symptom, immunometabolic, genetic and lifestyle data from a population of young adults (24 years) in the Avon Longitudinal Study of Parents and Children (ALSPAC).



Raul Santos-Rodrigues, Professor of Data Science and Intelligent Systems, School of Engineering Mathematics and Technology, University of Bristol

Perceptual metrics and audio representation learning

The subjective quality of natural signals can be approximated with objective perceptual metrics. Designed to approximate the perceptual behaviour of human observers, perceptual metrics often reflect structures found in natural signals and neurological pathways. We investigate the feasibility of utilizing state-of-the-art image perceptual metrics for evaluating audio signals by representing them as spectrograms. We evaluate the effectiveness of our proposed metric using a music dataset -- with promising results in terms of the correlation between the metrics and the perceived quality of audio as rated by human evaluators. We also show how models trained with perceptual metrics as loss functions can capture perceptually meaningful features from the structures held within these metrics, leading to improved performance on audio processing tasks.

11.15 Panel discussion and questions

Chair: Liz Coulthard, Professor of Cognitive Neurology, Bristol Medical School

11.35: Coffee and discussion

12:05: Keynote

Jianfeng Feng, Professor, Department of Computer Science, University of Warwick

From multi-omic data to digital twin brain

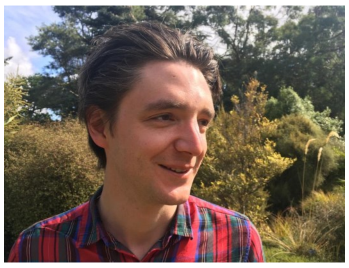
AI and proteomics are recently believed as facing a revolutionary phase and could fundamentally change our understanding of diseases (brain disorders). Using one of the typical mental disorders and AD as examples, we explore the etiology of the disease with genomic, proteomic and other type of omic data and novel AI algorithms. The discoveries subsequently enable us to subtype various diseases and then develop different treatment strategies in TMS and drug therapy.

Some further developments aiming to integrate micro-, meso- and macroscopic data results are discussed. Furthermore, equipped with the knowledge we have about the brain, we developed a model of the whole human brain at the neuronal level (digital twin brain, DTB): 86B neurons and 100T synapses(parameters). Examples on applying DTB to medical applications are included.

Chair: Paul Anastasiades, Senior Lecturer in Neuroscience, Bristol Medical School, University of Bristol

12:45: Free and intellectually Stimulating lunch

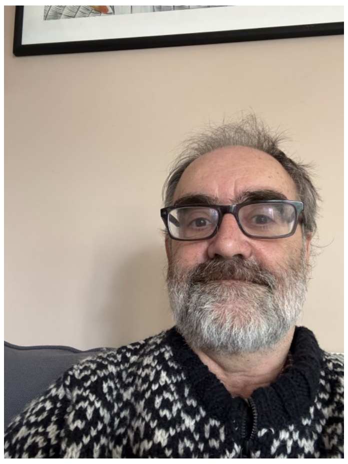
13.40: Modelling Intelligence - part 1



Laurence Aitchison, Lecturer, School of Engineering Mathematics and Technology, University of Bristol

Mechanistic interpretability: the computational neuroscience of modern LLMs

This talk explores the emerging field of mechanistic interpretability, which seeks to reverse engineer and understand the internal operations of large language models. I argue that there are many connections to computational neuroscience in terms of methods and mindset. I give an overview of some of our work in this area, where we are trying to sparsify computations, not just activations.

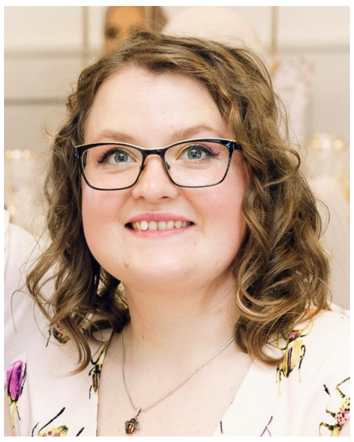


Jeffrey Bowers, Professor, School of Psychological Science, University of Bristol

Similarities between artificial neural networks (ANNs) and humans are greatly exaggerated: A case-study of Brain-Score.

Many studies have shown that ANN models of biological vision and language can predict neural activation in visual and language brain regions. This is taken as evidence that ANNs represent information like brains. Unfortunately, the factors underlying these predictions are poorly understood.

I describe a study that reveals the visual features of images that drive predictions in V4 and IT visual cortex. Although good predictions have been taken to support the conclusion that ANNs are good models of "core object recognition", it turns out that the predictions have little to do with the objects in the images. The findings highlight a more general problem in the methods researchers used to compare ANNs to human across a wide range of domains.



Sophie Baker, PhD student, School of Engineering Mathematics and Technology, University of Bristol

Degeneracy in Embodied Choice

Perceptual decision-making provides a framework for understanding how organisms translate sensory evidence into actions, but traditional models face challenges in explaining choice phenomena and motor integration. Despite evidence of both covert and overt motor processes during deliberation, most frameworks treat movement as merely implementing a completed decision.

We explore the relationship between action and decision making by extending a proposed framework for embodied choice and independently varying the influence of motor feedback on internal choice variables and the contribution of evidence to action. This new model, Degenerate Embodied Choice (DEC), arbitrates between parallel and embodied theories of choice. We demonstrate that DEC replicates the speed-accuracy trade-off (SAT) degenerately, with embodiment proving both necessary and unique for trading speed and accuracy across urgent and accuracy-emphasised tasks. DEC emulates empirical data both qualitatively and quantitatively, with model-fitted parameters falling exclusively within the embodied set and producing congruent predictive SAT values within a narrow band. We then introduce the Optimality Framework for Embodied Choice (OFEC) as a lens for examining embodied choice through optimality principles.

Our findings suggest that complex decision behaviours can emerge from simple underlying principles, whether through geometric properties of decision boundaries or motor-cognitive integration.

Chair: Paul Chadderton, Associate Professor in Neurophysiology, School of Physiology, Pharmacology & Neuroscience, University of Bristol

14.20: New & breaking short talks

Alexander Hepburn, Senior Research Associate, School of Engineering Mathematics and Technology, University of Bristol

Evaluating colour constancy in neural networks

Colour constancy is the ability to perceive colours as constant, even when under various illuminations and is a 'low-level' behaviour of the human visual system (HVS). For example, we are able to determine the colour of an object whether it is under natural sunlight, or in an environment lit with a tungsten light bulb. In order to evaluate artificial neural networks in their ability to replicate this psychophysical behaviour, we generate synthetic stimuli of known hue, lightness and chroma, and evaluate the networks performance when the stimuli is presented under different illuminations. In this talk, I will describe the stimuli generated, test methodology, and results when evaluating one network.

Imogen Kruse, Post Graduate Researcher, School of Psychological Science, University of Bristol

Connectivity evidence indicates a role for the parietal lobe in decision-making, and enables identification of intraparietal areas IP2 as a likely correlate for Interpreted Controllability

The Controllability Hypothesis proposes a parietal mechanism which computes the extent to which constructs are perceived as controllable or achievable ('Interpreted Controllability' (IC)). IC influences motivation and decision-making by generating higher expected value and action values for controllable constructs. IC may be elevated during negative emotional states to motivate aversive outcome avoidance.

Human Effective Connectivity (EC) data were used to identify brain areas involved in IC computation. Resting-state EC data revealed bi-directional connectivity between newly-emerged intraparietal area IP2 and orbitofrontal and anterior cingulate areas, (implicated in expected and action value respectively, and in affective experience) which was largely absent for other parietal areas. These findings implicate IP2 in IC computation. This conclusion is further supported by location of IP2, and studies finding IP2 activation in association with events linked to IC, such as viewing reachable objects, risky decision-making, non-reward and pain. Possible interventions/ theory tests include ultrasonic deactivation of IP2.

Abiola Saka, PhD Student, CDT Digital Health and Care, University of Bristol

The Interplay between Cognitive Deficits and the Risk of Psychosis: The Role of Sleep

This PhD research study investigates the complex interplay between sleep disturbances, cognitive deficits, and psychiatric risk in young adolescents, especially in individuals with CNV 22q11.2 Deletion Syndrome (22q11.2DS). The study combines multi-modal data collection, including using Fitbit, EEG headband, Gamified set of cognitive tasks, and sleep diaries. The overarching aim is to develop longitudinal metrics of sleep and circadian rhythms that can inform precision psychiatry.

Tsvetoslav Ivanov, PhD student, Computational Neuroscience Unit, University of Bristol

Dopamine D1 receptor expression in prefrontal parvalbumin neurons influences distractibility across species

Marmosets and macaques are common non-human primate models of cognition, yet marmosets appear more distractible and may perform more poorly in cognitive tasks. The dorsolateral prefrontal cortex (dlPFC) is pivotal for regulating attention, and prior research in macaques suggests that dopaminergic modulation and inhibitory parvalbumin (PV) neurons could contribute to distractibility. Thus, we compared the two species using a visual fixation task with distractors, performed molecular and anatomical analyses of dlPFC, and linked functional microcircuitry with cognitive performance using computational modeling. We found that marmosets are more distractible than macaques, and that marmoset dlPFC PV neurons contain higher levels of dopamine-1 receptor (D1R) transcripts and protein, like levels in mice. The modeling indicated that higher D1R expression in marmoset dlPFC PV neurons may increase distractibility by making dlPFC microcircuits more vulnerable to disruptions of their task-related persistent activity, especially when dopamine is released in dlPFC in response to salient stimuli.

Ben Thewlis, PhD Student, Bristol Medical School, University of Bristol

X-CLARITY for 3D Mapping of Bone Marrow-Neuron Fusion in Transplanted Mouse Brains

Bone marrow-derived cell (BMDC) fusion with neurons represents a fascinating phenomenon with exciting implications for brain repair. In fusing together, BMDCs transfer healthy nuclei to damaged neurons leading to repair and restoration in the ability to process and transmit information. Our current research investigates this process within the cerebellum by transplanting EGFP-labelled bone marrow cells into myeloablated mice. Following perfusion and brain extraction, we use X-CLARITY to achieve whole-brain tissue clearing and enable high-resolution imaging.

Using light-sheet microscopy we are able to reconstruct the brains in 3D, providing novel insights into the frequency and localisation of fused neurons. Our next steps include quantifying fused neurons and mapping their distribution throughout the brain based on morphology and EGFP expression. We aim to compare fusion rates and patterns across brain regions as well as different mouse models of neurodegenerative diseases, shedding light on the fusion mechanisms and disease-specific dynamics.

Eva Sevenster, PhD Student, School of Engineering Mathematics and Technology, University of Bristol

Learning dopamine release for flexible working memory

Working memory is crucial for flexible cognition. However, the neural mechanisms behind maintenance and manipulation of information in working memory remain not fully understood. Here, we propose that dopamine release in the prefrontal cortex (PFC) plays a crucial role in shaping working memory representations by increasing neuronal time constants. We use a biologically inspired recurrent neural network (RNN) with feedback controller to model the mesocortical loop from the ventral tegmental area (VTA) to the PFC. Instead of modulating RNN hidden activity directly, the feedback controller modulates the timescales of the individual RNN units, mimicking the shift to slower NMDA-dependent activity that results from dopamine release from VTA projections to the cortex. We train the model on a delayed-association task and show that this mechanism helps to learn robust and flexible task representations during the delay period.

Sunil Mamotra, Academic Clinical Fellow in Ophthalmology, Bristol Medical School, University of Bristol

Machine Learning Models applied to Slit-Lamp Imaging of the Eye

Referrals to the hospital eye service, the busiest outpatient specialty in the NHS are usually based upon findings from slit-lamp examination. Our group has piloted novel implementations of imaging systems for the slit-lamp microscope to improve workflow but also to facilitate the development of machine learning models. We have been able to develop a machine learning model which is able to diagnose, grade and segment video sequences based upon videos from clinical examination. There are endless possibilities for the use of this technology including decision support for less experienced clinicians, auto-documentation, assistive tools for clinicians as well as the ability to identify disease that would otherwise not have been possible. The latter is particularly relevant given that researchers have already demonstrated the potential to identify systemic diseases using machine learning models from retinal photographs and the fact that the eye manifests many systemic diseases.

William Antcliff, PhD Student, Comparative Biomedical Sciences, Royal Veterinary College, University of London

Quantifying Neurodevelopmental Impacts of Urban Particulate Matter in Zebrafish Using Topological Data Analysis

Zebrafish are widely used as a model for studying early vertebrate development, providing a unique platform to explore neural changes within the developing brain. Embryos were exposed to Urban Particulate Matter (UPM) during the immediate days post-fertilisation to investigate the developmental impacts of environmental pollutants. High-resolution imaging of zebrafish midbrains—believed to be responsible for learning and memory—was performed to assess potential structural alterations caused by UPM exposure. To quantify these changes, a novel approach using topological data analysis (TDA) was employed, enabling the identification and measurement of intricate structural features within the midbrain's neural architecture. This method offers a powerful tool for analysing complex biological image data. Additionally, an image analysis pipeline was developed and applied across multiple high-resolution images, demonstrating its scalability and reproducibility for large datasets. This study underscores the utility of TDA in developmental neurotoxicology and highlights its potential for broader applications in image-based biological research.

Clair Booth, Research Technician, School of Physiology, Pharmacology & Neuroscience, Bristol University

Automated measurement of rodent exploratory behaviour for neurosciences

Spontaneous exploration of objects is a commonly used method to assess memory in rodents. Object exploration has traditionally been measured manually by a human scorer watching videos post-hoc, however this method is time consuming and subject to human error, bias, and scorer fatigue. Here we present an automated scoring method utilising 1) DeepLabCut (Mathis et al. 2018) to track multiple animal body parts, 2) Segment Anything Model (Kirillov et al. 2023; Meta AI) to identify object boundaries, and 3) custom Matlab code to determine when the animal is nearby and looking towards an object. The resulting exploration times largely correlate with ground truth exploration and perform at a similar level of accuracy to a range of human scorers, however some non-exploratory behaviours are included (e.g. grooming near an object). Whilst some further refinement is required, initial results suggest automated scoring is a highly useful tool in behavioural neuroscience.

Dabal Pedamonti, Senior Research Associate, School of Engineering Mathematics and Technology, University of Bristol

Psilocybin enables flexible learning reinstating plasticity in fixed synapses

Psilocybin, a natural psychedelic compound, is gaining attention as a promising treatment for some mental illnesses due to its low dependency risks and clinical benefits for patients. Although it appears to destabilise neural connectivity while enhancing cognitive flexibility, its underlying mechanism and influence on subjects performing active tasks and learning remain unexplored. Guided by anatomical evidence of serotonin pathways targeted by psilocybin, we propose a recurrent reinforcement learning model that adjusts plasticity in specific cortical regions to improve the model's task flexibility. Existing deep reinforcement learning methods often suffer from plasticity loss when dealing with non-stationary tasks, where targets and objectives continuously shift. By drawing parallels with biological studies, our findings suggest that psilocybin-inspired modulation restores plasticity and alters neuronal dynamics in a manner comparable to empirical observations. This model is an initial step to assess testable prediction about how psilocybin works.

Aswathi Thrivikraman, PhD Student, School of Computer Science, University of Bristol

Model-Based Reinforcement Learning as a Computational Framework for Mind Wandering

Mind wandering reflects the brain's remarkable ability to flexibly reallocate attention and plan for the future, often beyond immediate task demands. In this talk, I present a computational framework using model-based reinforcement learning to simulate this cognitive phenomenon. The model integrates two tasks: a repetitive, low-reward model-free task and a strategic, high-reward model-based task. The agent dynamically switches between acting and "mind wandering," driven by task rewards and "boredom-induced" exploration. Preliminary results show emergent behaviours mirroring human cognitive patterns, where the agent shifts focus to optimise long-term rewards by strategically planning for future tasks. These results align with the Opportunity Cost Theory of Motivational Attention, providing insights into how cognitive resources are reallocated when current tasks lose their utility. This work bridges neuroscience and AI by formalising mind wandering as a reward-driven process, capturing the interplay between task engagement and spontaneous thought, while opening pathways to understand cognitive flexibility.

Andrew Shannon, PhD Student, Centre for Doctoral Training in Interactive AI, University of Bristol

Modelling Nonlinear Oscillator Networks with Hybrid Reservoir Computing

Modelling the brain remains challenging, in part, due to discrepancies between analytical models and real-world complexity. Physics-informed, hybrid, machine learning promises to bridge this gap by combining the knowledge encoded in analytical models with data. We consider a network of nonlinear oscillators, a common abstraction of neural activity, and investigate the potential of a hybrid approach. We show that hybrid reservoir computing improves the accuracy of network activity forecasts compared to standard reservoir computing or analytical models alone. This is the case even where the hybrid reservoir's "expert" model lacks significant aspects of the non-linear coupling present in the ground truth network.

15.10: Break and discussion

15.25: Modelling Intelligence - part 2

Conor Houghton, Associate Professor in Computer Science, School of Engineering Mathematics and Technology, University of Bristol

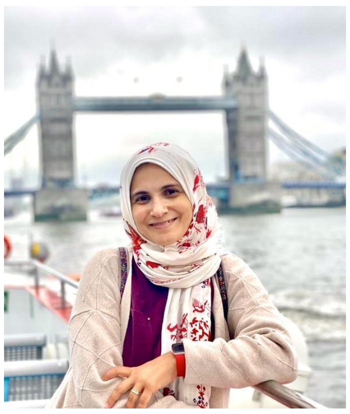
What machine learning might tell us about the evolution of language

The iterated learning model (ILM) was a simple neural-network agent model used by Simon Kirby and co-workers to model language change. In the ILM a tutor teaches a pupil a simple language using a limited random set of examples; the pupil then becomes a tutor itself and teaches a new pupil. Since it only learned a subset of the language it is forced to generalize to produce its own examples. The interesting thing is that the language evolves expressivity and compositionality through the resulting cycles of generalization and subselection. The original ILM included an unrealistic step, basically to make a map that goes both ways, meanings to signals and signals to meaning, the pupil needed to do a sort of inversion. It is as if a child stayed silent until 12 and then imagined everything they could ever possibly say before doing some complicated mathematics and only then starting to speak. We found a way of removing this, but to do that we need to add an autoencoder step to learning in the neural networks. This is akin to incorporating reflection into leaning, or language into thought. This leads me to suggest that a crucial step in the evolution of our language ability occurred when we started to use our utterances to organize thought, much as chain-of-thought reasoning helps LLMs perform more useful inference.

Edwin Dalmaijer, Lecturer, School of Psychological Science, University of Bristol

Bird brains in navigation and (bin) warfare

Brains are among the most complex phenomena that humans study, and the most advanced artificial intelligence falls short of even approaching true brain function. In this talk, I will make an argument for abstraction in artificial intelligence: to understand and optimise agent behaviour, sometimes all we need is a model of actions, social networks, and rewards. Using the example of avian navigation, I will show how generations of artificial agents with minimal cognitive complexity can optimise a route-finding problem. Then, using the example of bird-human bin warfare, I will illustrate how hierarchical reinforcement learning can empower artificial agents to compete in an arms race.



Zahraa Abdallah, Senior Lecturer, School of Engineering Mathematics and Technology, University of Bristol

Machine Learning Approaches for Early Detection of Neurodegenerative Diseases

Neurodegenerative diseases, such as Alzheimer's and Parkinson's, affect millions worldwide, with Alzheimer's alone impacting over 55 million people—a figure expected to double by 2050. These progressive conditions impose a substantial burden on individuals, families, and healthcare systems, highlighting the critical need for early detection to enable timely intervention and better outcomes. This talk delves into machine learning (ML) approaches for identifying biomarkers associated with disease progression, drawing on diverse data sources such as EEG signals, radiology scans, and clinical records. Each study harnesses specific data modalities, including brain activity in EEG-based Parkinson's research and imaging-based in Alzheimer's studies, to uncover subtle patterns indicative of early disease onset. By addressing key challenges like data heterogeneity and interpretability, we demonstrate how ML advances early detection efforts and deepens our understanding of neurodegenerative diseases

16.05: Interactive panel discussion

Speakers from Modelling Intelligence Parts 1 & 2 and keynote

Chair: Matt Jones, Professor in Neuroscience, School of Physiology, Pharmacology & Neuroscience, University of Bristol

16.30: Event close

Elizabeth Blackwell Institute

University of Bristol
Jean Golding Institute

We hope you enjoy the event!

Please provide feedback via the QR code →

Keep in touch! Sign up to become a member of our communities:

Jean Golding Institute mailing list – UoB only

Jean Golding Institute mailing list non-UoB

Elizabeth Blackwell Institute mailing list

Bristol Neuroscience Network community membership form