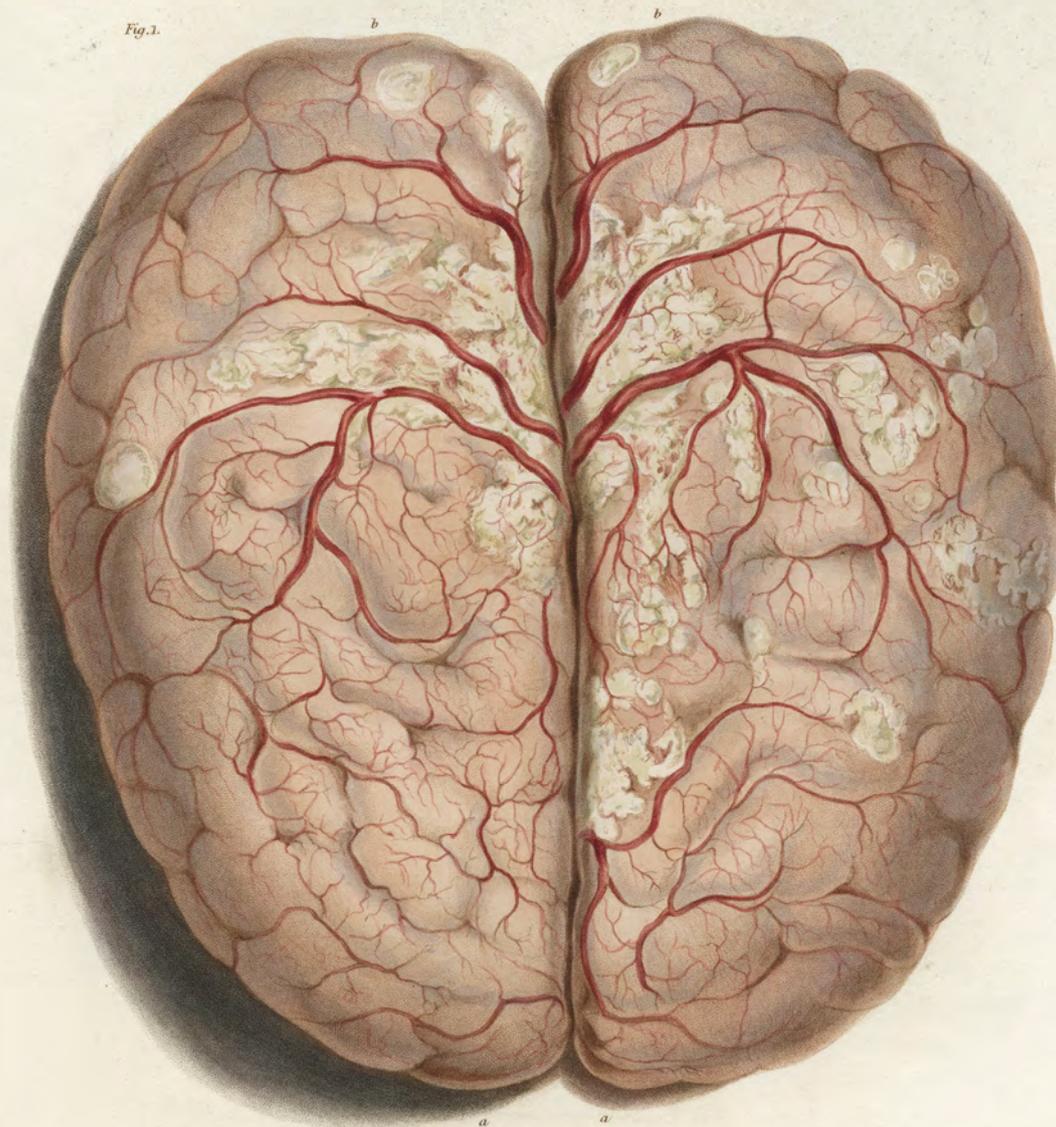


# PERCEPTUAL PROCESSES IN THE BRAIN AND IN COMPUTATIONAL MODELS BILATERAL INTERNATIONAL MEETING

18 – 19 SEPTEMBER 2024

Organised by the Royal Society and  
The Israel Academy of Sciences and Humanities



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ROYAL  
SOCIETY

האקדמיה הלאומית הישראלית למדעים  
المجمع الوطني الإسرائيلي للعلوم والآداب  
THE ISRAEL ACADEMY OF SCIENCES AND HUMANITIES



This meeting is part of the Royal Society scientific programme – connecting scientists from around the world in discussions which influence their field and inspire future research opportunities.

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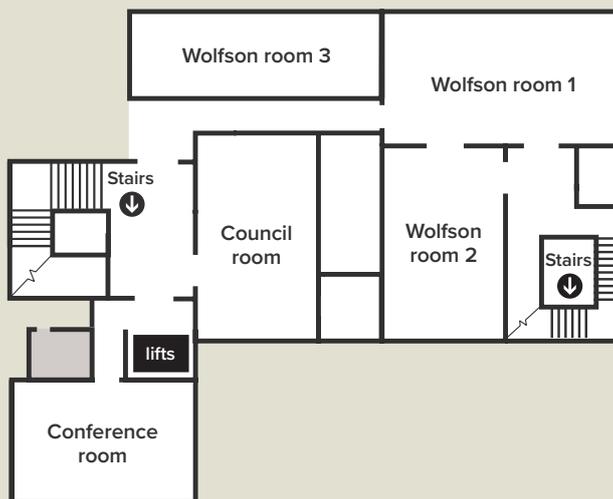
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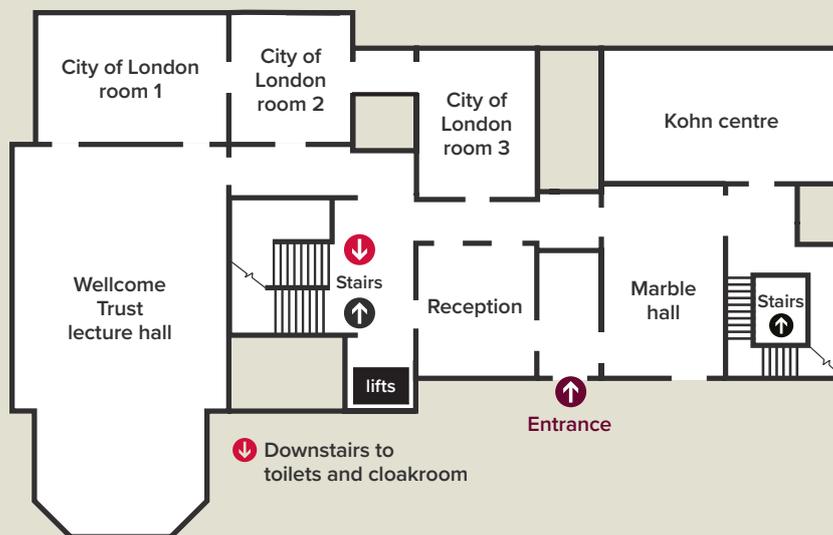
Name **RS-Public**  
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## First floor



## Ground floor



## Basement



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## The Israel Academy of Sciences and Humanities

The Israel Academy of Sciences and Humanities is the preeminent scientific institution in Israel. It was established by law in 1961 and acts as a national focal point for Israeli scholarship in all branches of the sciences, social sciences, and humanities.

The Academy comprises 154 of Israel's most distinguished scientists and scholars who operate in two divisions—the Sciences Division and the Humanities Division. It is tasked with promoting Israeli scientific excellence; advising the government on scientific matters of national interest; publishing scholarly research of lasting merit; and maintaining active contact with the broader international scientific and scholarly community.

For more information, visit: **[www.academy.ac.il](http://www.academy.ac.il)**

## Programme day 1

### 18 September 2024

During the lunch hour on both days, the Royal Society library team will conduct show and tell sessions of some of the most notable papers, records, books and journals within our archives. The colour sticker on your name badge will determine which group you are in.

|   |   |
|---|---|
| 8.30am  | Registration  |
| 8.50am  | Welcome and introduction<br>Sir Mark Walport, Foreign Secretary of the Royal Society<br>Professor David Harel, President of the Israel Academy of Sciences and Humanities |
| <b>Session 1: Artificial and natural computations in sensory perception, chaired by Professor Shimon Ullman</b> |   |
| 9am   | Professor Shimon Ullman, Weizmann Institute of Science  |
| 9.30am  | Professor Maneesh Sahani, Gatsby Unit, UCL  |
| 10am  | Professor Michal Irani, Weizmann Institute of Science   |
| 10.30am   | Networking break  |
| 11am  | Professor Simon Laughlin, University of Cambridge   |
| 11.30am   | Professor Oren Shriki, Ben Gurion University of the Negev   |
| 12 noon   | Dr Nicol Harper, Oxford University  |
| 12.30pm   | Lunch – Mercer room (Basement)  |
| Royal Society Library Team to conduct archive show and tell sessions  |   |
| 12.30pm   | Green group to Library Reading Room   |
| 1.10pm  | Red group to Library Reading Room   |
| <b>Session 2: Context-dependent and multi-sensory signal processing, chaired by Professor Andrew King</b>       |   |
| 1.30pm  | Professor David Harel, Weizmann Institute of Science  |
| 2pm   | Professor Jennifer Linden, UCL Ear Institute  |
| 2.30pm  | Professor Randy Bruno, University of Oxford   |
| 3pm   | Networking break  |
| 3.30pm  | Dr Sylvia Schröder, University of Sussex  |
| 4pm   | Professor Noam Sobel, Weizmann Institute  |
| 4.30pm  | Professor Amir Amedi, Reichman University   |

**Programme day 2**  
19 September 2024

|  |   |
|--|---|
| 8.45am   | Coffee/networking                                       |
| <b>Session 3: Coding the sensory world, chaired by Professor Andrew King</b> |   |
| 9am  | Professor Rafi Malach, Weizmann Institute of Science    |
| 9.30am   | Professor Peter Latham, UCL                             |
| 10am   | Professor Galit Yovel, Tel Aviv University              |
| 10.30am  | Networking break  |
| 11am   | Professor Rasmus Petersen, University of Manchester     |
| 11.30am  | Professor Gal Kaminka, Bar-Ilan University              |
| 12 noon  | Dr Andreas Schaefer, Francis Crick Institute            |
| 12.30pm  | Lunch "Mercer" Basement level                           |
| Royal Society Library Team to conduct Archive show and tell sessions         |   |
| 1.10pm   | Blue group to Library Reading Room                      |
| <b>Session 4: Sensory loss, chaired by Professor Amir Amedi</b>              |   |
| 1.30pm   | Professor Andrew King, University of Oxford             |
| 2pm  | Professor Yael Henkin, Tel Aviv University              |
| 2.30pm   | Professor Mairéad MacSweeney, University College London |
| 3pm  | Networking break  |
| 3.20pm   | Dr Daniel-Robert Chebat, Ariel University               |
| 3.50pm   | Professor Tamar Makin, University of Cambridge          |
| 4.20pm   | Professor Liad Mudrik, Tel Aviv University              |
| 4.50pm   | Closing remarks   |
| 5pm  | Event close   |

## Meeting day 1

Wednesday 18 September 2024

### Welcome and introduction



#### **Sir Mark Walport FMedSci FRS**

The Royal Society

Sir Mark Walport is Foreign Secretary and Vice-President of the Royal Society. He chairs Imperial College Health Partners, Imperial College Academic Health Sciences Centre and the Kennedy Memorial Trust. He is a non-executive board member of NHS England, and trustee of the British Museum, the Daiwa Anglo-Japanese Foundation, and Health Data Research UK.

Previous career highlights include:

Founding Chief Executive of UK Research and Innovation (UKRI), 2017 – 2020.

Government Chief Scientific Adviser (GCSA), 2013 – 2017.

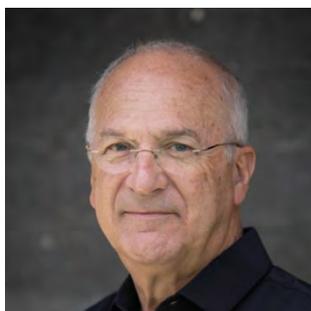
Member and latterly co-chair of the Prime Minister's Council for Science and Technology

Director of the Wellcome Trust.

Professor and Head of the Division of Medicine, Imperial College London.

Founder Fellow and first Registrar of the Academy of Medical Sciences.

Member of the Advisory Board of Infrastructure UK.

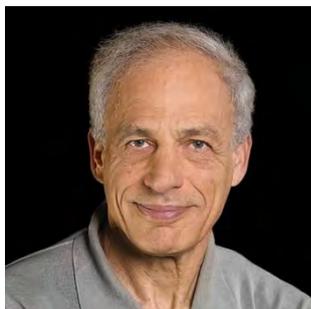


#### **Professor David Harel FRS**

Weizmann Institute of Science and  
Israel Academy of Sciences and Humanities

David Harel is President of the Israel Academy of Sciences and Humanities, and a computer scientist who has been at the Weizmann Institute since 1980. He has worked on computability theory, logics of programs, database theory, automata theory, software and systems engineering, visual languages, graph layout, modelling biological systems, odour synthesis and communication, and prosody analysis. He invented Statecharts, co-invented Live Sequence Charts, and co-designed Statemate, Rhapsody, the Play-Engine and PlayGo. His awards include the ACM Karlstrom Outstanding Educator Award, the Israel Prize, the ACM Software System Award, the Emet Prize, the IEEE Harlan Mills Award, and six honorary degrees. He is a Fellow of ACM, IEEE, EATCS and AAAS, a member or international member of Academia Europaea, US National Academy of Sciences, US National Academy of Engineering, American Academy of Arts and Sciences, and the Chinese Academy of Sciences, and is a Fellow of the Royal Society (FRS).

## Session 1: Artificial and natural computations in sensory perception



### **Chair: Professor Shimon Ullman**

Weizmann Institute of Science, Israel

Shimon Ullman is a professor of computer science at the Weizmann Institute of Science, and the head of the Weizmann Artificial Intelligence Institute. Prior to this position, he was a Professor at the Brain and Cognitive Science and the AI Laboratory at Massachusetts Institute of Technology (MIT). His areas of research combine computer and human vision, human cognition, and brain modelling.

He obtained his BSc in Mathematics, Physics and Biology, at the Hebrew University of Jerusalem, and PhD in Electrical Engineering and Computer Sciences, at the Artificial Intelligence Laboratory in the Massachusetts Institute of Technology. He is a recipient of the 2008 David E Rumelhart Prize in human cognition, the 2014 Emet Prize for Art, Science and Culture, the 2015 Israel Prize in Computer Science, and the 2019 IEEE Azriel Rosenfeld Award for lifetime achievement in computer vision. He is a member of the Israeli Academy of Sciences and Humanities, and the American Academy of Arts and Sciences.

### **Scene interpretation in humans and machines**

Understanding a visual scene is a daunting and still unsolved task, since scenes can contain a large number of objects with their parts and subparts, their properties, and inter-relations. Extracting the full scene structure is therefore infeasible, but it is also unnecessary, since it is usually sufficient to extract a partial scene structure, which depends on the observer's goal and interest. I will describe a model that has a human-like ability to perform such a partial interpretation, focusing on scene structures of interest, evolving sequentially, in a goal-directed manner. The model uses a cortex-like combination of bottom-up and top-down networks, where the goal is achieved by automatically providing a sequence of top-down instructions that guide the process in an efficient manner, which also generalises broadly across different scene structures. A similar model structure could be adopted in vision-language deep network models, potentially leading to a substantial improvement in their ability to achieve advanced scene understanding.



### **Professor Maneesh Sahani**

Gatsby Unit, UCL, UK

Maneesh Sahani is Professor of Theoretical Neuroscience and Machine Learning and Director of the Gatsby Computational Neuroscience Unit at University College London (UCL). He received his PhD in 1999 from the Computation and Neural Systems program at Caltech under the supervision of Richard Andersen and John Hopfield. After postdoctoral work in the Gatsby Unit and at UCSF, he joined the faculty at Gatsby in 2004, becoming Director in 2017. His work spans the interface of the fields of machine learning and neuroscience, with particular emphasis on the computations underlying inference and control under uncertainty, in perceptual and motor cortical systems.

#### **Learning to infer without generation**

That inference is fundamental to perceptual processing has been recognised since at least the time of Helmholtz. Effective inference depends on the integration of noisy and ambiguous sensory input with an accurate internal model of the sensory world. Robustness (and biological constraints) requires that this model and the characteristics of the sensory input be learnt and updated from experience, usually without any separate access to the world-state that is to be inferred. Although the mathematical framework for inference itself is well worked out, less is known about the algorithms that might underlie such learning. Instead, much work on unsupervised learning has, particularly recently, focused on data generation rather than on inference. I will outline a novel framework for unsupervised learning, which makes it possible to learn to recognise latent structure underlying sensory data accurately, and with optimal sensory fusion, but without generation. Such "recognition-parametrised models" may hold the key to data-driven and adaptive inferential computation in artificial and natural perceptual systems.



### **Professor Michal Irani,**

Weizmann Institute of Science, Israel

Michal Irani is a Professor at the Weizmann Institute of Science, Israel. She joined the Weizmann Institute in 1997, where she is currently the Dean of the Faculty of Mathematics and Computer-Science. Michal's research interests centre around Computer-Vision, Image-Processing, Artificial-Intelligence, and Video information analysis. She also works on decoding visual information from Brain activity. Michal received a BSc degree in Mathematics and Computer Science from the Hebrew University of Jerusalem, and MSc and PhD degrees in Computer Science from the same institution. During 1993-1996 she was a member of the Vision Technologies Laboratory at the Sarnoff Research Center (Princeton).

Michal's prizes and honours include the David Sarnoff Research Center Technical Achievement Award (1994), the Yigal Alon three-year Fellowship for Outstanding Young Scientists (1998), the Morris L Levinson Prize in Mathematics (2003), the Maria Petrou Prize (awarded by the IAPR) for outstanding contributions to the fields of Computer Vision and Pattern Recognition (2016), the Landau Prize in Artificial Intelligence (2019), and the Rothschild Prize in Mathematics and Computer Science (2020). In 2023 Michal was elected member of the Israel Academy of Sciences and Humanities. Michal also received several Best-Paper awards in prestigious conferences (ECCV'2000, ICCV'2001, ECCV'2002, ICCV'2005), and in 2017 she received the Helmholtz Prize – the “Test of Time Award” (for the paper “Actions as space-time shapes”).

### **‘Mind reading’: Self-supervised decoding of visual data from brain activity**

1. Can we reconstruct images/videos that a person saw, directly from his/her fMRI brain recordings?
2. Can we reconstruct the training data that a deep-network trained on, directly from the parameters of the network?

The answer to both of these intriguing questions is “Yes!” In this talk I will show our work in both of these domains. Furthermore, exploring the two in tandem, under a single computational framework, can lead to significant breakthroughs in both fields. I will show how combining the power of both domains can potentially be used to bridge the gap between Minds and Machines.



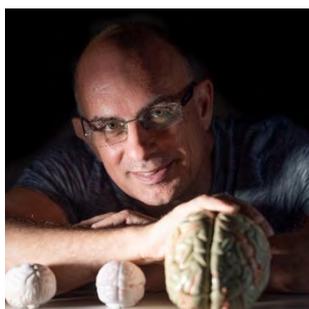
### **Professor Simon Laughlin FRS** Zoology, University of Cambridge, UK

Simon Laughlin studies insect visual systems to discover organisational principles. Following his PhD at the Australian National University (1974), he continued to work in Canberra with physicists and engineers, pioneering the application information theory to natural image statistics to show that neurons optimise coding, and demonstrating their use of predictive coding. After joining Cambridge Zoology Department in 1984 he continued this inter-disciplinary approach, investigating the ecology of phototransduction, motion coding, multi-sensory integration, the information capacity of analogue neurons, and most recently, neuronal energy efficiency. He and Peter Sterling co-authored the award-winning book, *Principles of Neural Design*.

### **A visual system’s first circuit is designed to compute at low cost**

Biological systems tend to use resources efficiently and brains are no exception. In both insects and vertebrates, the first stage of

visual processing improves efficiency by eliminating redundancy. The mechanisms used are remarkably similar. Signalling is analogue, photoreceptors use high gain, high vesicle release rate output synapses; each pre-synaptic release site drives several post-synaptic elements; redundancy is reduced by regulating the release of synaptic vesicles; and non-vesicular signalling mechanisms act on photoreceptors' pre-synaptic terminals to regulate vesicle release. These mechanisms greatly reduce the number of pre-synaptic release sites required to achieve a given signal-to-noise ratio for transmission from photoreceptors to second order neurons and, according to longstanding connectomic data from flies, this reduces the consumption of space, materials and energy by an order of magnitude. Thus the efficient implementation of efficient coding demonstrates two means of reducing the cost of computation within a neural circuit. 1. Apply feed-back and feed forward pre-synaptically to minimise neurotransmitter release. 2. Exploit the versatility of the brain's winning technology, molecular cell biology, to compute compactly within the extracellular space of synaptic complexes.



### **Professor Oren Shriki**

Ben Gurion University of the Negev, Israel

Professor Shriki completed undergraduate studies in physics and doctoral studies in computational neuroscience at the Hebrew University, Jerusalem. Following a postdoctoral period at the National Institute of Mental Health (Bethesda, MD, USA), he established the Computational Psychiatry and Neurotechnology Lab at Ben-Gurion University of the Negev. Research in his lab uses mathematical analyses of brain activity and a wide range of machine and deep learning algorithms to develop novel diagnostic tools for neurological and psychiatric disorders. Another line of research in the lab focuses on brain-computer interfaces. To promote the field of neurotechnology, he established a community of students centred around the topic and a NeuroTech hub, a physical space equipped with state-of-the-art equipment, which allows students to work on relevant projects. In early 2021, Professor Shriki co-founded NeuroHelp, a startup company that develops a novel wearable system for epileptic seizure detection and prediction.

### **Edge of Perception: Optimal Information Representation, Criticality and Hallucinations in Recurrent Networks**

The framework of critical brain dynamics, which proposes that the brain operates near the boundary between two distinct dynamical states, has garnered significant interest over the past two decades. This talk will explore a neuronal network model characterised by recurrent connections that evolve through learning rules designed to optimise information representation within the network. These rules enable the network to adapt dynamically to the input statistics, often positioning it near a critical state. Under certain conditions, such as diminished external input

or increased plasticity, the network may transition into a phase characterised by spontaneous pattern formation, which can be interpreted as hallucinations. The theory will be illustrated through applications related to early visual processing, tinnitus, and synaesthesia. Additionally, the presentation will introduce a criticality-based framework for category-specific recall, offering new insights into how recurrent neuronal networks can replicate complex brain functions.



**Dr Nicol Harper**  
University of Oxford, UK

Nicol Harper completed his PhD in optimal coding in the auditory system at University College London with David McAlpine, with six months in the lab of Shihab Shamma at the University of Maryland, College Park. After this he secured a Sir Henry Wellcome Postdoctoral Fellowship, splitting his time between the Redwood Centre for Theoretical Neuroscience lead by Bruno Olshausen at the University of California, Berkeley, and the Auditory Neuroscience Group lead by Andrew King at the University of Oxford. He is now an Associate Professor with the Auditory Neuroscience Group where he researches normative principles and stimulus encoding in sensory neural systems.

### **Temporal prediction as a sensory processing principle**

Sensory systems display a dizzying complexity of tuning properties and circuitry. Why do neurons in sensory pathways show the properties we observe, instead of the many other possibilities? We investigate whether a simple principle can explain these properties - temporal prediction. This proposes that sensory systems are optimised to efficiently predict immediate future sensory input given recent past input for natural stimuli. This may be useful for guiding future action, uncovering underlying variables, and discarding irrelevant information. We found that simple feedforward networks optimised for temporal prediction on spectrograms of natural sounds produced units with tuning properties resembling those of neurons in primary auditory cortex. When instead optimised for retinal-filtered movies of natural scenes the tuning properties resembled those of simple cells in primary visual cortex. When applied to natural sound waveforms or unfiltered movies, these networks produced units with tuning properties resembling those of neurons in the auditory nerve or the retinogeniculate pathway respectively. Application of temporal prediction hierarchically to the activity of these retinogeniculate-like units produced units resembling visual cortical simple cells, complex cells and pattern-motion selective cells as one moves up the hierarchy.

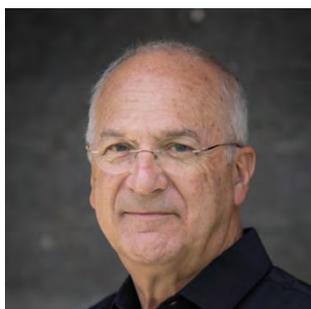
## Session 2: Context-dependent and multi-sensory signal processing



### **Chair: Professor Andrew King FRS**

University of Oxford, UK

Andrew King is a Wellcome Principal Research Fellow, Professor of Neurophysiology, and Director of the Centre for Integrative Neuroscience in the Department of Physiology, Anatomy and Genetics at the University of Oxford. He studied physiology at King's College London and obtained his PhD from the MRC National Institute for Medical Research. Apart from a spell as a visiting scientist at the Eye Research Institute in Boston, he has worked at the University of Oxford since then. Andrew's research uses a combination of experimental and computational approaches to investigate how the auditory brain adapts to the rapidly changing statistics that characterise real-life soundscapes, integrates other sensory and motor-related signals, and learns to compensate for the altered inputs resulting from hearing impairments. He is a winner of the Wellcome Prize in Physiology and a Fellow of the Royal Society, the Academy of Medical Sciences and the Physiological Society.



### **Professor David Harel FRS**

Weizmann Institute of Science, Israel

#### **Towards deciphering prosody – the 'music of speech'**

Non-verbal signals in speech, collectively termed "prosody", carry a large amount of important information, ranging from conversation action to attitude and emotion. Despite its importance, little is known about the way that the human brain is able to decipher such signals, and the principles that govern prosodic structure. We believe that both issues are linked to the multi-layered nature of prosodic messages – the fact that one segment of "spoken music" conveys different orders of information simultaneously.

We have developed an analytical schema and an automated procedure for the disentanglement of prosodic messages. Currently, we are able to deal with prosodic boundaries, unit prototypes, emphasis, and emotion. This was done by fine-tuning a pre-trained speech recognition model, coupled with a specific process of data preparation.

The ideas have the potential of greatly enhancing speech-recognition systems, automatic translation, speech synthesis and non-verbal signaling for the disabled. In addition, they may well contribute to a better understanding of the distinctive features of prosodic disentanglement, which, in turn, will shed light on human deciphering of non-verbal speech signals.



### **Professor Jennifer Linden**

UCL Ear Institute, UK

Jennifer F Linden PhD is Professor of Neuroscience at UCL and Director of the UCL Ear Institute. She is interested in the neural mechanisms that enable us to listen effectively in noisy environments. She also seeks to understand how those neural mechanisms go awry in developmental disorders, schizophrenia, tinnitus and other disorders affecting listening ability. The Linden lab studies neural mechanisms of auditory perception in mice, humans, and computer models. For further details, see [www.ucl.ac.uk/ear/research/lindenlab](http://www.ucl.ac.uk/ear/research/lindenlab).

#### **Putting sounds in context: nonlinear sensitivity to sound combinations in the auditory cortex**

The perceptual salience of a sound depends on the acoustic context in which it appears. Neural correlates of this contextual sensitivity can be estimated from responses to complex sounds using the nonlinear-linear "context model". Context models provide estimates of both the principal (spectrotemporal) receptive field of a neuron and a "contextual gain field" describing its nonlinear sensitivity to local acoustic context. In this talk I will summarise previously published and more recent results from analysis of auditory cortical responses to complex sounds using context models. The work has revealed strong neuron-specific patterns of nonlinear sensitivity to sound combinations in auditory cortical neurons. These neuron-specific patterns remain surprisingly stable across days of recording in awake mice. Thus, nonlinear sensitivity to local acoustic context appears to be an integral and stable feature of the neural code in the auditory cortex.



### **Professor Randy Bruno**

University of Oxford, UK

Randy Bruno is a Professor of Neuroscience in the Department of Physiology, Anatomy & Genetics at the University of Oxford. His research focuses on how cortical microcircuits enable perception and learning. The lab combines a battery of sophisticated mouse behaviours with optogenetic manipulation, two-photon microscopy, intracellular and array electrophysiology, and computational modeling. He is particularly interested in the contributions of the different cortical layers to behaviour and the role of secondary thalamus. He earned a BS in Cognitive Science from Carnegie Mellon University and a PhD in Neurobiology from the University of Pittsburgh School of Medicine. At the Max Planck Institute for Medical Research in Heidelberg, Germany, he was a postdoctoral researcher with the Nobel laureate Bert Sakmann, who co-

invented patch clamp recording. Prior to arriving in Oxford, Professor Bruno was an Assistant and Associate Professor at Columbia University. The Society for Neuroscience recognised his research with its Young Investigator Award.

### **Cortical layers in context and learning**

Perception, decision making, and movement deeply involve cortical circuitry, which has a stereotyped architecture repeated across the entire surface of the brain. In this talk, I will discuss our investigations of how the different cortical layers contribute to behaviour. I will show how modern optogenetic and traditional lesion manipulations can lead to opposing conclusions about the necessity of a brain structure, layer, or cell type. We have developed novel cortex-dependent tasks for the rodent whisker system in which we manipulate and record the layers to test their functions. By combining array recordings and modeling in these tasks, we are additionally able to disentangle the contributions of sensory, motor, choice, and reward signals to the activity of individual neurons. We find that task context can reweight this mixture so dramatically that the most fundamental features of cortex, such as topographic representations disappear. On-going experiments using two-photon microscopy of apical tuft dendrites during animal training suggest that cortical layer 1 may be a key substrate by which learning alters the geometry of representations in sensory cortex according to task context.



**Dr Sylvia Schröder**  
University of Sussex, UK

Dr Sylvia Schröder is a Sir Henry Dale Fellow in the field of systems visual neuroscience at the University of Sussex. Using techniques like two-photon imaging and high-density electrophysiology in the mouse model, Sylvia's lab investigates how behaviour and internal states affect visual processing and the animal's performance in visually dependent tasks.

As a postdoctoral researcher in the lab of Matteo Carandini and Kenneth Harris at UCL, Sylvia pioneered the functional recording from single retinal axons in awake mice and discovered that pre-cortical visual responses in the retina and superior colliculus reflect behavioural state variables such as arousal and locomotion. More recently, Sylvia's lab demonstrated that neurons in the visual colliculus also respond to rewards. It was previously believed that behavioural modulation of visual responses occurred centrally; Sylvia's work fundamentally changes our understanding in that it demonstrates an intricate weaving together of sensory and non-sensory information, much earlier in the visual pathway. This opens exciting new questions concerning how non-sensory information is communicated across the brain to regulate sensation.

During her PhD with Kevan Martin at ETH Zurich, Sylvia studied the functional architecture of cat primary visual cortex revealing an unexpected degree of functional heterogeneity within the cortical column, most notable in response to complex natural stimuli. This finding has informed studies on cortical topographic maps, cortical population coding, learning and memory.

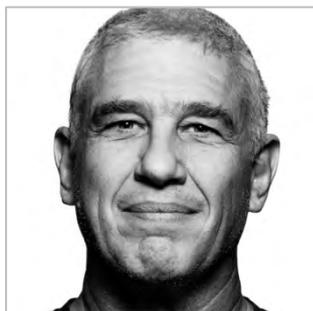
### **The impact of motor behaviour and internal states on subcortical visual processing**

The early visual system is thought to efficiently encode visual input, eg by adapting to the recent stimulus history. Based on similar arguments, early visual processing could benefit from adapting to the animal's current behaviour, its goals and internal states as these different contexts change the expected stimulus statistics and the importance of specific visual features. Indeed, we find that contextual modulation is evident as early as in the output of the retina and in neurons of the superficial superior colliculus receiving direct retinal input.

Using two-photon imaging of calcium signals, we have recorded responses of large populations of neurons in the superior colliculus (SC) and of retinal axons projecting to the SC in awake mice engaged in different behaviours. When mice were running, spontaneous activity in about half of the recorded retinal axons and SC neurons was either enhanced or suppressed compared to stationary periods. Interestingly, the effect of running on visually driven activity was dependent on the visual input. While running had purely linear effects on the tuning to motion direction, ie changing the gain or offset of responses, running shifted neurons' preferences on average towards higher visual motion speeds, which indicates that neurons are better equipped to encode fast visual motion during running.

Independent of the effects of running and arousal, we found that receiving water reward is an additional modulator of visual responses. Reward consistently increased responses to successive visual stimuli in about 20% of recorded SC neurons. These effects by reward could not be explained by pupil-linked arousal or body movements. The increase of visual responses after receiving water reward led to improved decoding of stimulus presence from the neural population activity.

These results show that behavioural and internal state contexts affect visual processing at a very early stage, possibly to optimise the efficiency of stimulus encoding and motivationally driven encoding.



### **Professor Noam Sobel**

Weizmann Institute of Science, Israel

Professor Noam Sobel is a neuroscientist and a professor in the Department of Brain Sciences at the Weizmann Institute of Science in Rehovot, Israel. He completed his PhD in neuroscience at Stanford University and a postdoctoral fellowship at the California Institute of Technology. Before joining the Weizmann Institute, he was a professor at the Helen Wills Neuroscience Institute at the University of California, Berkeley.

Professor Sobel's research focuses on the neurobiological mechanisms of the human olfactory system, exploring how the brain processes smells and their impact on behaviour, emotions, and social interactions. His work has led to significant discoveries, such as a metric for measuring smells, and novel devices that measure and/or emit odours. These devices help measure and predict brain responses to smells and have practical applications in medical diagnostics and aiding communication for disabled individuals. His contributions to neuroscience have been recognised with numerous awards, including the Rappaport Prize for Biomedical Sciences in 2012.

#### **Telesmell: From the perceptual laws of olfaction to transmitting odours over wire.**

Wavelength is a physical measure of light, and the intricate understanding of its link to perceived colour enabled digitisation of the visual seen. By contrast, scientists have been unable to develop a physical measure linked to perceived smell. To generate such a measure, we collected perceptual similarity estimates of 49,788 pairwise odorants from 199 participants who smelled 242 different multicomponent odorants and used these data to refine a predictive model that links odorant structure to odorant perception. The resulting measure combines 21 physicochemical features of the odorants into a single number—expressed in radians—that accurately predicts the extent of perceptual similarity between multicomponent odorant pairs. Using this model, we are able to identify sets of primary odorants that can be mixed to achieve any target odorants within a prescribed perceptual space. With this in hand, we are currently establishing telesmell: a system that measures an odorant at one location, characterises the odour within our feature-space, transmits this over wire to a remote location, where a device mixes primary odorants to recreate the target odour.



**Professor Amir Amedi**  
Reichman University, Israel

Amir Amedi is a Professor in the School of Psychology and School of Medicine in Reichman University, Israel and Adjunct Professor at the Sorbonne University. He is founding director of The Baruch Ivcher Institute for Brain, Cognition & Technology & The Ruth and Meir Rosental Brain Imaging Centre which studies the human brain, its interface with technology, science, and medicine for various conditions like sensory, neurological and neuro-immunological conditions. Prior to joining the University, Amir was a Professor at the Department of Medical Neurobiology & Cognitive Sciences at the Hebrew University where he also did his PhD studies in Computational Neuroscience. Amir's background is multidisciplinary with training in computational neuroscience (PhD 2005), brain imaging, neurology (Visiting Research Fellow at NIH and Instructor of Neurology at Harvard Medical School), and music. Amir also holds several patents in the field of multisensory integration and brain plasticity. His work has been featured in the NYT, Nature, Science, Washington Post, National Geographic Wire & New Scientist among others. His lab is well funded by 4 EU grants including ERC grants BrainVisionRehab 2013-2018; And How Experience Shapes the human brain: NovelExperieSENSE 2019-2023 as well as GuestXR and ERC-POC on touch technologies for hearing impairments. He is the recipient of several prizes including The Krill prize from the Wolf Foundation and Scholar Award in Understanding Human Cognition from The James S. McDonnell Foundation

**Nature vs. nurture in brain organisation: insights from visual loss and blindfolding protocols in the developing vs. adult brain plasticity and new scalable clinical interventions**

Neuroinflammation and chronic stress contribute significantly to brain degeneration in normal aging and in degenerative diseases, affecting brain areas that compute spatial and verbal cognition and memory. Studies show that clinical psychological interventions offer promise in mitigating inflammation and chronic stress and thus potentially slowing degenerative brain pathologies. Alongside, studies from our lab showed that visual deprivation can lead to superior memory in early blindness, and that various training protocols in the adult brain that include visual deprivation holds potential to induce neuroplasticity via strengthening of weak existing brain connectivity. In the talk I will present various recent studies evaluated the effect of a comprehensive digital psychocognitive multisensory training on the association between brain plasticity and the immune system in individuals with subjective cognitive decline (SCD) and on individuals with high levels of anxiety and depression. Participants followed a 2-6 weeks of daily half-hour digital training protocol. The protocol utilises egocentric and allocentric Hebb-Williams based maze solving strategies, audio-visual navigation cues, and gradual masking vision techniques alongside with various methods from clinical psychology to reduce stress and anxiety (eg attention training

techniques and cognitive based therapy). Study endpoints encompass brain resting-state functional connectivity (rsFC), DTI and salivary and blood immunological biomarker levels. Following training, there were large scale changes in a set of inflammatory biomarkers that are correlated with changes in areas that are tightly linked to brain degeneration with age and with depression and anxiety. These findings suggest that our combined psycho-cognitive intervention and multisensory approach that include a component of sensory visual deprivation induces a synergetic effect on both brain function and neuroinflammation. As alternations in the middle temporal cortex (including the hippocampus), Default Mode Network and the Salience network, as well as increased levels of various pro-inflammatory cytokines, are associated with the aging process and Alzheimer's disease, these findings suggest a promising positive impact on the aging brain in clinical brain degeneration and in mental health diseases.

## Meeting day 2

Thursday 19 September 2024

### Session 3: Coding the sensory world

**Chair: Professor Andrew King FRS**

University of Oxford, UK



**Professor Rafi Malach**

Weizmann Institute of Science, Israel

Professor Rafael Malach received his PhD in Physiological Optics (1982) from the University of California at Berkeley and did a postdoctoral research at MIT. Since 1985, he is a member of the Brain Sciences Department at the Weizmann Institute. In 2022 he received the EMET Prize in the life sciences.

Malach's central research aim is to uncover principles by which the human brain underlies the emergence of high level cognitive behaviors and the boundary between conscious and sub-conscious processes. To that end he combines functional brain imaging using magnetic resonance with invasive electrophysiological recordings, performed for diagnostic purposes in patients. His group studies brain activity patterns and their link to conscious visual perception, memory processes and free and creative behaviors. His group has published over 170 papers.

#### **The role of neuronal relational structures in human visual perception**

Contrary to prevailing perspectives- perceptual contents do not depend solely on visual inputs and can be elicited via non-visual routes such as electrical stimulation, epileptic auras, imagery and more. What appears to consistently determine perceptual content is the anatomical location of the neuronal

activations. Here, I will discuss a relational coding scheme, echoing classical structuralist notions, that can account for these constraints. In relational coding, perceptual content is not determined by the stimulus-specific neuronal activation pattern (the population vector) but by the unique local synaptic structure in which this activation appears. This structure can be revealed, experimentally, through the matrix of similarity distances between all activation patterns belonging to the same category.

Experimental evidence, derived from intra-cranial recordings conducted in patients for clinical purposes, will be presented, indicating that such relational coding can explain perceptual similarity judgments in human observers and can account for social shared vision. Importantly, "convergent evolution" is revealed between human and AI relational structures- which

allows a novel approach to studying the functional specialisations of these structures. Finally, I will discuss the role of recurrent activity in expressing the relational coding in the human visual cortex and its possible link to conscious vision.



### **Professor Peter Latham**

Gatsby Computational Neuroscience Unit, UCL, UK

Peter Latham is Professor of Theoretical Neuroscience at the Gatsby Computational Neuroscience Unit, UCL. He received his PhD in physics from the University of California, Berkeley, and spent 10 years working on plasma physics at the University of Maryland. He switched to neuroscience in 1996 with a brief stint and NIH, followed by a slightly longer stint at the University of California, Los Angeles. In 2004 he became a faculty member at the Gatsby Computational Neuroscience Unit, UCL, where he has been ever since. He is interested in understanding how biologically realistic networks carry out computations, with a focus on probabilistic inference and deep learning. His work borrows heavily from physics and machine learning.

#### **How does learning affect brain structure?**

Brains exhibit a large range of cell types, connectivity patterns, and organisational structures, at both micro and macro scales. To make sense of these structures, neuroscientists often take a normative approach, and ask: what circuits, and connection strengths, lead to optimal performance? Often ignored in these studies, however, is the fact that connection strengths have to be learned. Since the efficiency of learning depends crucially on architecture, especially when a limited number of trials are available, we expect learning constraints to have a large impact on neural structures. Based on this observation, we hypothesise that evolution optimised the brain for efficient learning. For concreteness, we apply this hypothesis to the early olfactory circuits of mammals and insects, where we recover known scaling laws. In principle the techniques we use can – and should – be applied to any system.



### **Professor Galit Yovel**

Tel Aviv University, Israel

Professor Galit Yovel is a faculty member in the school of Psychological Science and the Sagol School of Neuroscience. Professor Yovel completed her BA in Psychology and Philosophy at Tel Aviv University, a PhD in Psychology at the University of Chicago and a post-doctoral training in the Department of Brain and Cognitive Sciences at MIT. Professor Yovel is studying the cognitive and neural mechanisms of human face recognition. She is interested in the way visual, social and semantic information is

integrated in the representation of faces in perception and memory. She has been combining multiple experimental techniques including psychophysics, neuroimaging (EEG, fMRI, TMS), eye tracking as well as visual and semantic deep learning algorithms.

### **What can deep learning tell us about human face recognition?**

Deep convolutional neural networks have recently reached human-level performance in face recognition. But how effective are they as computational models of human face recognition? What insights can they offer about the human system? Our recent studies revealed significant similarities between the visual face representations of humans and face-trained deep convolutional neural networks. However, we found that human face representations go beyond vision, and that semantic representations from large language model further predict the representation of faces in human memory. Overall, the capacity of current deep learning algorithms to generate human-like, high-level visual and semantic representations offer valuable insights into the nature and functioning of human mental representations.



**Professor Rasmus Petersen**  
University of Manchester, UK

Rasmus Petersen is Professor of Neuroscience at the University of Manchester. Rasmus studied at the University of Oxford and received his PhD from King's College London. Rasmus is known for contributions to our understanding of how signals are encoded by neuronal spike trains, including the role of precise spike timing using the whiskers as a model system. Current work focusses on sensory coding in freely moving animals during natural exploratory behaviour.

### **Function of the somatosensory cortex in freely moving mice**

The ultimate purpose of sensory systems is to guide behaviour. Yet the bulk of textbook knowledge of sensory systems comes from experiments on anaesthetised animals where the motor systems are disengaged. The broad aim of our work is to investigate the neural basis of sensation in the brain of animals engaged in natural, freely moving behaviour. To this end, we have combined chronic electrophysiological recording of neural activity in the whisker primary somatosensory cortex (wS1) of freely moving mice with video-based reconstruction of mouse posture in 3D. As expected of wS1 neurons, the best predictor of firing rate was whisker-object touch. Our most striking finding was that sensorimotor variables describing the pose (and changes in pose) of the head/body explained substantial firing rate variance beyond that accounted for by touch. Different neurons were

sensitive to distinct combinations of touch and head/body pose. These results challenge the classic feedforward sensory processing framework and suggest that, under the natural conditions of freely movement, neurons in primary sensory cortex signal touch in the context of the state of the body.



### **Professor Gal Kaminka**

Bar-Ilan University, Israel

Professor Gal Kaminka is a professor at the Computer Science Department in Bar Ilan University, where he conducts research in social artificial intelligence.

Professor Kaminka seeks to understand how a single mind become a part of a collective, by conducting research in areas spanning robot team and swarms, agents in virtual environments, molecular robotics, and robot theory of mind. He is a Fellow of the European Association for AI (EurAI), a former Fellow of the Radcliffe Institute at Harvard, and was among the youngest recipients of the prestigious national (Israel) Landau award for science excellence. He has held positions on the executive boards of leading scientific organisations, and is also a co-founder and former CTO of Bladeranger, developing robots for cleaning solar power installations. Recently, he has been investigating the complex connections between rationality, heterogeneity, and learning, in natural, synthetic, and hybrid swarms (eg locusts and robots).

### **Proprioception, Visual Perception, and Computation in Natural and Robot Swarms**

Swarms (both natural and artificial) permeate our technological, biological, and sociological worlds. They have inspired generations of researchers who seek to understand how a single (computational) mind becomes part of a collective. This talk focuses on the individual swarm member, and the connections between its proprioception, exteroception, and computational capabilities.

Using examples from experiments with locusts and robots, I will argue these connections are important in both biology and robotics, but are often overlooked in mathematical models of individual decision-making. I will then present components of a novel model of individual decision-making, which we believe better accounts for realistic sensor and perceptual limitations, while utilising only modest computational resources. Specifically, the model admits visual perception without conspecific recognition, and errors in proprioception. It explains observations of natural phenomena (such as pause-and-go motions), and---when used with robots---is amenable to adaptation processes that improve swarm behavior.



**Dr Andreas Schaefer**  
Francis Crick Institute, UK

Andreas Schaefer is a Principal Group Leader of the Sensory Circuits and Neurotechnology Laboratory and Assistant Research Director at the Francis Crick Institute, and co-founder of Paradromics, Inc.

Andreas obtained a Diplomach in Physics and a PhD in Neuroscience at the Max-Planck-Institute for Medical Research in Heidelberg, Germany. After postdoctoral work at UCL he established his own lab at UCL and the Max-Planck-Institute. In 2010 he was appointed Professor and Chair of Neuroanatomy at the University of Heidelberg; he moved to the Francis Crick Institute and UCL as Professor of Neuroscience in 2013. His research focuses on developing behavioural and neurotechnology tools and dissecting the cellular mechanisms of information processing in the brain combining in vivo physiology with behaviour, anatomy, and machine learning. In recent years his lab has pioneered combining synchrotron X-ray tomography with in vivo physiology and volume electron microscopy to dissect the anatomical logic underlying information processing in the brain.

**Of odour plumes and synchrotrons: Structure and function of neural circuits**

A central aspect to computation in the brain is to elucidate how information is transformed by the neural circuits of brain regions, how inputs are transformed to outputs. Here, I will discuss how we approach this work in the mouse olfactory system. Odours in natural settings are transported by complex, often turbulent airflows. I will discuss the information that is contained in the spatiotemporal odour plume structure, how it is represented in the mammalian brain, and how this can be accessed behaviourally. We will then use these rich odour stimuli to probe representation and processing across brain areas. To link function to structure and directly elucidate how information is transformed in early sensory areas, I will introduce correlative multimodal imaging approaches, centring around different synchrotron X-ray tomography techniques. These enable us to directly identify the anatomy of neurons previously functionally imaged in vivo across mm<sup>3</sup> volumes. Specifically, it allows us to identify output channels corresponding to a given input channel in the olfactory bulb. Thereby we can resolve how different “sister” projection neurons differentially represent the external sensory world. Finally, I will discuss how such X-ray tomography methods can be developed to enable multimodal imaging of mm<sup>3</sup> tissues with synaptic resolution, paving the way for dissecting neural circuit anatomy across brain areas in a scalable way.

## Session 4: Sensory loss

**Chair: Professor Amir Amedi**  
Reichman University, Israel



**Professor Andrew King FRS**  
University of Oxford, UK

### **Learning to compensate for unilateral hearing loss**

A capacity to adapt to abnormal inputs is critical for maintaining perceptual abilities in individuals with sensory impairments. We have shown that the auditory system can compensate for changes in the balance of inputs between the two ears, both during development and in later life, and maintain accurate sound localisation in spite of reduced hearing in one ear. Our research in animals and humans has demonstrated that this can be achieved either through adaptive shifts in neuronal sensitivity to the altered binaural cues or by reweighting different spatial cues according to their relative reliability. Our recent findings suggest that adaptation to unilateral conductive hearing loss generalises to untrained sounds and to more challenging listening conditions. Furthermore, studies in animals using optogenetic silencing and electrophysiological recording during behavioural adaptation to unilateral conductive hearing loss are helping to elucidate the neural circuits and physiological changes responsible for the experience-dependent recovery of spatial hearing. Finally, the use of virtual reality displays is providing an opportunity to explore the potential therapeutic applications of this plasticity in human listeners.



**Professor Yael Henkin**  
Tel Aviv University, Israel

Professor Yael Henkin is Head of the Hearing, Speech, and Language Center, Co-director of the Cochlear Implant Program, and Head of Communication Disorders Services at the Sheba Medical Center, Tel Hashomer. She manages a diverse spectrum of diagnostic and therapeutic activities in the field of communication disorders. Professor Henkin is a senior faculty member in the Department of Communication Disorders, Faculty of Medicine at Tel Aviv University. Her research focuses on neurophysiological biomarkers of auditory speech processing across the life span, in normal hearing and hearing-impaired listeners habilitated by hearing aids and cochlear implants. Professor Henkin was president of the International Symposium on Objective Measures in Auditory Implants (OMAI) 2018, that took place in Tel Aviv, Israel. Her work is supported by research

funding from the German Research Society (DFG) and from the cochlear implant industry.

### **Restoration of sensory loss: Auditory plasticity and function following rehabilitation by means of cochlear implants and hearing aids**

Cochlear implants (CI) are one of the most successful neuroprosthetic devices ever developed enabling speech perception after complete loss of auditory input. Over 30 years of cochlear implantation have provided a unique opportunity to explore the effect of sensory restoration across different models of deafness. In a series of studies utilising brain-based (EEG) and behavioral measures, the trajectory and activation patterns of auditory cortical processing-spanning from initial sensory to later perceptual stages, were investigated. Examined cohorts encompass both pediatric and adult patients, spanning those with pre- and post-lingual bilateral deafness who were rehabilitated through unilateral CI, bilateral CI, or unilateral CI paired with a hearing aid. The scope extends to children with unilateral deafness who were rehabilitated via a CI or a hearing aid. Results showing that AERPs' timing, strength and source localisation varied as a function of habilitation mode, listening condition, stimulus type, and CI laterality will be depicted and discussed. Broadly, AERPs reflecting cortical speech processing of CI recipients were prolonged and less synchronous, reflecting differential bottom-up and top-down strategies. Finally, current ongoing research adding time frequency representations (oscillatory bands) as complementary biomarkers of cortical speech processing will be presented.



**Professor Mairéad MacSweeney**  
University College London, UK

Mairéad MacSweeney is a Wellcome Trust Senior Research Fellow. She is the leader of the Visual Communication Research Group at UCL Institute of Cognitive Neuroscience. She is also a member of the UCL Deafness, Cognition and Language Research Centre (DCAL). In her research she examines the impact of altered sensory and language experience on cognition, language and the brain. She does this by working with people born profoundly deaf and those who use a sign language. Her research focusses on sign language, speechreading, and reading of written English. Advances in this field are not only of theoretical interest regarding brain plasticity and how the brain processes language, but also have the potential to have important clinical and educational implications for deaf children and adults.

**Title: Insights into neuroplasticity from deaf people and sign language users**

The consequences of deafness on plasticity in the brain is reasonably well documented. To what extent this neuroplasticity is also influenced by altered language experience is less well established. I will review research, of my own and that of others, that has investigated this issue in deaf adults and children using a range of neuroimaging methods (fMRI; fNIRS; fTCD). Although the results are variable, all studies support the argument that it is vital to take language experience into account when considering the impact of 'sensory loss' on neuroplasticity. In my talk I will address a range of factors to be considered, including the impact of language modality, the age of sign language acquisition and the impact of language deprivation.



### **Dr Daniel-Robert Chebat**

Ariel University, Israel

Dr Daniel-Robert Chebat is a distinguished researcher renowned for groundbreaking work on brain plasticity, navigation, and sensory substitution. His work has particularly focused on the navigational abilities of congenitally blind individuals using sensory substitution devices (SSDs), and their neural correlates. He has demonstrated that individuals born blind who utilise SSDs possess the capacity to navigate obstacle courses, recognise and navigate virtual routes, and even learn maze-solving strategies. His recent publications show that three functional "scene selective" regions in the visual cortex (ie the Parahippocampal Place Area -PPA, the Occipital Place Area- OPA and the RetroSplenial Complex-RSC) respond to auditory stimuli when humans perform navigation tasks. Dr Chebat completed his PhD in Neuropsychology from the University of Montreal, Canada, under the supervision of Professor Maurice Ptito. Later, making Alyiah to Israel Dr Chebat completed two post-doctoral stages at Professor Amir Amedi's lab, in neurobiology. Today, Dr Chebat is a Senior Lecturer/Researcher with Tenure at Ariel University, serving as the Scientific Director of the NARCA Research Center, and heading the Visual and Cognitive Neuroscience (VCN) Laboratory. Dr Chebat is a CIHR Research Fellow, recipient of the Azrieli Foundation Fellowship and of the Edmond & Lily Safra Center for Brain Sciences.

### **Perceptual Processes in the Congenitally Blind Brain: Insights from Spatial Perception and Sensory Adaptation**

Advances in understanding spatial navigation encompass diverse approaches, illuminating the acquisition of spatial knowledge among blind and sighted people. Notably, hippocampal reductions emerge in congenitally blind individuals, while sensory substitution devices (SSDs), exemplified by the Tongue Display Unit, or the EyeCane, reveal remarkable neuroplasticity. Our prior research revealed recruitment of primary visual areas in congenitally blind individuals while navigating via SSDs. Recently, we show the

recruitment of right V6 in navigation, even independently of sensory experience, unveiling its amodal nature. This echoes our previous findings of visual scene-selective areas repurposed for tactile or auditory spatial computations. Training-induced recruitment of V6 underscores its role in transforming sensory inputs for navigation. Strikingly, this transformation occurs even in the absence of visual experience. Our work unveils a neural hub for navigation and highlights cross-modal neural adaptability, expanding insights into spatial cognition.



**Professor Tamar Makin**  
University of Cambridge, UK

Tamar Makin is a Professor of Cognitive Neuroscience at the MRC Cognition and Brain Sciences Unit at Cambridge University and the leader of the Plasticity Lab [www.plasticity-lab.com](http://www.plasticity-lab.com). Her main interest is in understanding how our body representation changes in the brain (brain plasticity). Her primary model for this work is studying hand function and dysfunction, with a focus on how we could use technology to increase hand functionality in able and disabled individuals at all ages. Tamar graduated from the Brain and Behavioural Sciences programme at the Hebrew University of Jerusalem in 2009. She was then awarded several career development fellowships to establish her research programme on brain plasticity in amputees at the University of Oxford, first as Research Fellow and later as a Principle Investigator. She joined the faculty of UCL in 2016 and moved to Cambridge in 2022. She is currently supported by the UKRI (ERC Consolidator Grants > deferred to UKRI), the Wellcome Trust (Senior Research Fellow) and the UK Engineering and Physical Sciences Research Council, in addition to the UK Medical Research Council.

**Against brain reorganisation. Perspectives from individuals with acquired hand loss.**

Input loss has been claimed to facilitate a process known as reorganisation – whereby a brain area becomes physiologically reassigned to perform a qualitatively different brain function. In my talk I will revisit some of the classical animal and patient studies that spawned the notion of somatosensory reorganisation, highlighting conceptual, empirical and methodological problems that call this notion into doubt. Instead, I will demonstrate that brain representation of the missing hand persists decades after amputation. This alternative account advocates for radically different perspective on the opportunities and limitations for brain plasticity when designing artificial limbs for sensorimotor restoration.



**Professor Liad Mudrik**  
Tel Aviv University, Israel

Professor Liad Mudrik is a researcher at the school of psychological sciences and Sagol school of neuroscience at Tel Aviv University. Her research focuses on conscious experience, its neural mechanisms and functions. Mudrik completed two PhD dissertations at Tel Aviv University, in cognitive psychology and in philosophy. She then continued to a postdoctoral fellowship at the California Institute of Technology, in Christof Koch's lab. In 2019, she was selected as a member of the young Israeli academy of sciences. She is also one of the leaders of the Cogitate consortium, an international adversarial collaboration aimed at arbitrating between theories of consciousness, and the co-director of the CIFAR Brain, Mind and Consciousness program.

**From sensory coding to experiences: testing theories of consciousness**

Understanding how we code the sensory world is a huge challenge. Understanding how this coding translates into conscious experiences might even be a greater one. In recent decades, several neuroscientific theories for consciousness have tried to meet this challenge, attempting to explain the relations between neural activity and conscious experience. In this talk, I will provide a bird's-eye view of several leading theories, and critically examine how they have been empirically studied using the results of a large-scale quantitative and analytic review we conducted. I will then describe the first results of the Cogitate consortium – an adversarial collaboration aimed at testing two of these theories: the Global Neuronal Workspace and Integrated Information Theory. The results challenge both theories, and suggest ways by which we can further refine the search for the neural underpinnings of consciousness.

## **Closing remarks**

**Professor Amir Amedi**

Reichman University, Israel

**Professor Andrew King FRS**

The Royal Society and University of Oxford, UK

**Professor Shimon Ullman**

Weizmann Institute of Science, Israel

**Cover image**

The whole brain of an 11 year old showing tubercles. These can be seen as small white growths scattered across the surface.

Plate 29 from Bright's Medical Reports: Diseases of the brain and Nervous System part 2 by Richard Bright (London, Longman, Rees... 1831). Inscribed: 'Plate 29.C. J. Canton delin. London Published October 1st. 1830. by Longman, Rees, Orme & Brown. W. T. Fry sculp' Sarah Anne Drake (1803-1857), British botanical artist, was a long-term associate of the Lindley family and a prolific illustrator for James Lindley.

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