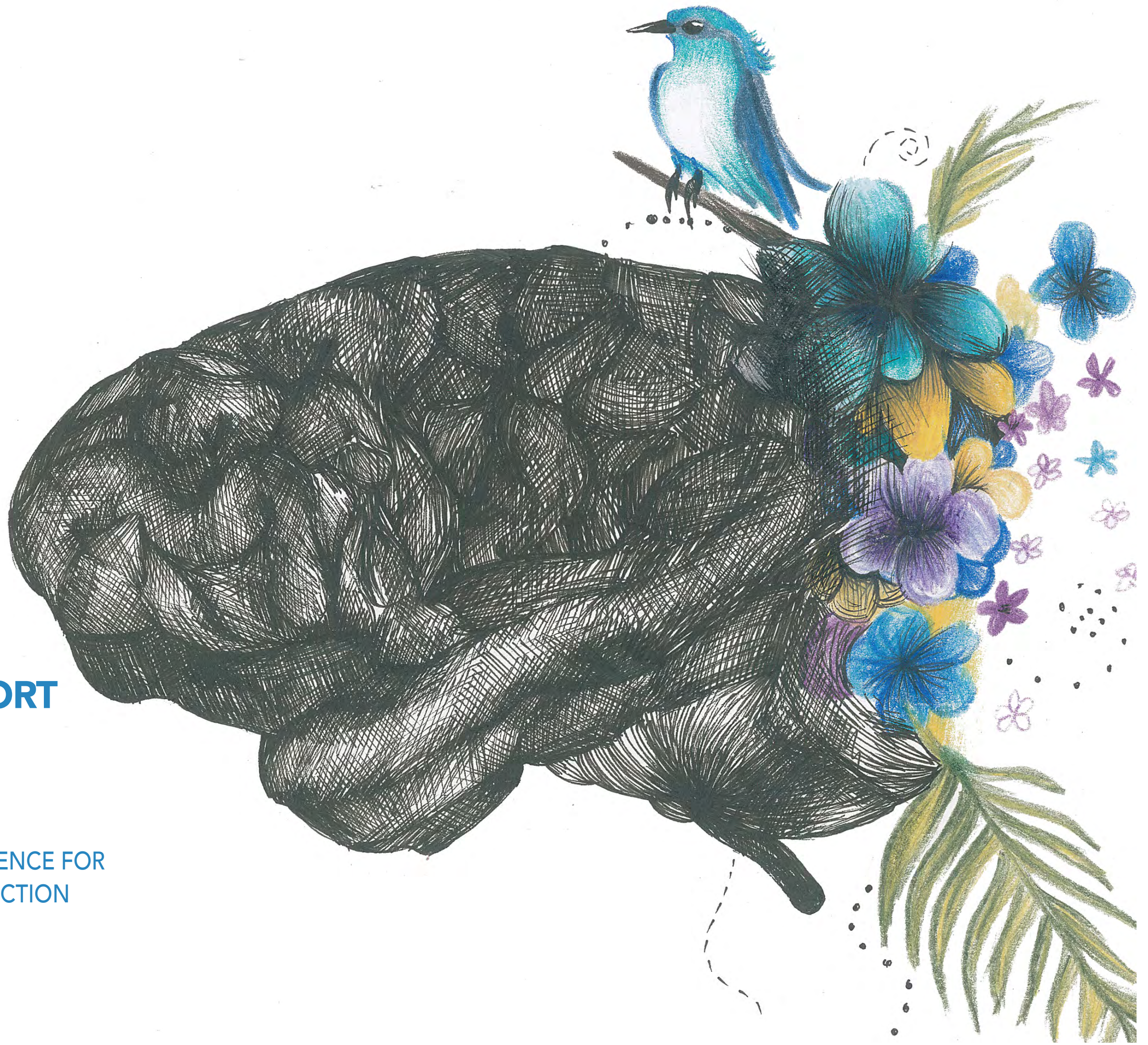


ANNUAL REPORT

2019

ARC CENTRE OF EXCELLENCE FOR  
INTEGRATIVE BRAIN FUNCTION





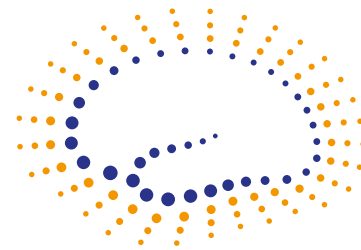
The ARC Centre of Excellence for Integrative Brain Function  
acknowledges the support of the  
Australian Research Council



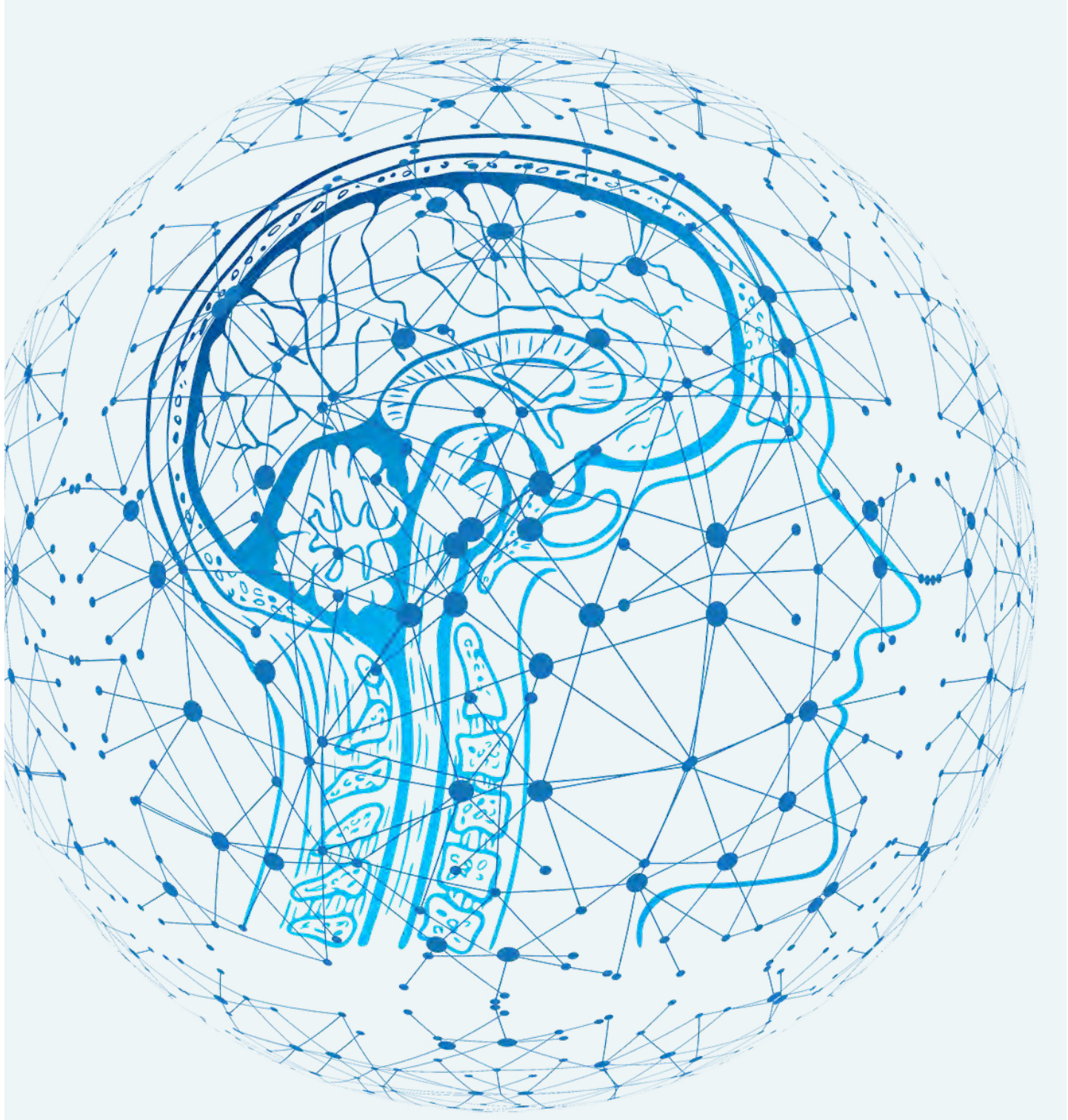
**Australian Government**

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**Australian Research Council**



Australian Research Council  
Centre of Excellence for  
Integrative Brain Function



Cover image courtesy of Tahlia H, QLD. 2016 Art competition winner.

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# INTRODUCTION

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## About

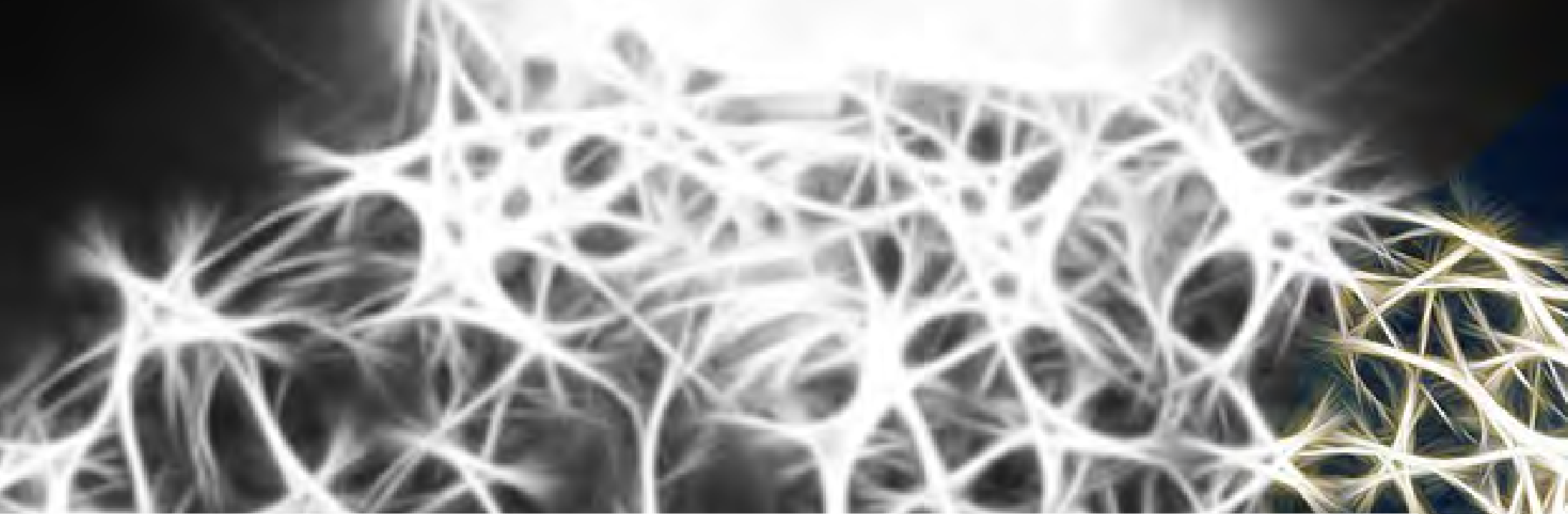
Understanding how the brain interacts with the world is one of the greatest challenges of the 21st century. The ARC Centre of Excellence for Integrative Brain Function (Brain Function CoE) was established in 2014 to address this challenge by facilitating collaborations amongst Australia’s leading brain researchers in the fields of brain anatomy and physiology, neural networks, neural circuits, brain systems, human behaviour and neurotechnologies. Led by Monash University, the Centre brings together researchers from The University of Queensland, The University of New South Wales, The University of Sydney, The Australian National University, and The University of Melbourne, alongside QIMR Berghofer, and eleven international Partner Organisations across Europe, Asia and North America.

By focusing on the complex brain functions that underlie three key integrative daily-life functions of attention, prediction and decision-making, Centre researchers are undertaking fundamental investigations into the principles of brain structure and function. The Centre is studying the relationship between brain activity and behaviour at multiple spatial and temporal scales – from nerve cell electrical and biochemical activity, through patterns of activity in large scale circuit networks to yield complex behaviour – to build an integrated model of how attention, prediction and decision-making occurs. This is being accomplished by a research program based on four interconnected themes: Cells and Synapses, Neural Circuits, Brain Systems, and Models, Technologies and Techniques. In parallel, Centre researchers are developing powerful predictive models of processes at each of the different scales to feed into the development of novel neural technologies for patentable devices and software.

Developing outstanding early career researchers (ECRs) in the neurosciences is critical to Australia’s international standing in science. The Centre is building internationally recognised excellence across the Australian neuroscience community by providing Centre ECRs with outstanding training and career development opportunities, and unique opportunities to acquire cross-disciplinary expertise.

Beyond research outcomes, the Centre is committed to maximising influence by disseminating research achievements and fostering discussion of emerging issues with stakeholders, both within academia and across the broader community. The Centre establishes new and strengthens existing connections between users of its research outputs, creates opportunities for new interdisciplinary research, and provides linkages to the broader scientific community and industry, both within Australia and globally.

The Centre aims to remain at the forefront of international research by engaging with international neuroscience initiatives, to ensure Australian neuroscientists provide an influential voice in the ethical, social and economic impact of brain research to the wider community.



“By focusing on the complex brain functions that underlie three key integrative daily-life functions of attention, prediction and decision-making, Centre researchers are undertaking fundamental investigations into the principles of brain structure and function.”

### VISION

To understand how the brain interacts with the world.

### MISSION

Undertake fundamental investigations into the principles of brain structure and function, by focusing on the complex brain functions that underlie attention, prediction and decision making.

### KEY INTEGRATIVE BRAIN FUNCTIONS

**Neural Basis of Attention**  
Understanding how attention regulates information processing in the brain.

**Neural Basis of Prediction**  
Testing the brain as a predictive machine model through multi-scale brain imaging experiments.

**Neural Basis of Decision**  
Quantify the link between sensory signals, resulting neuronal activity and generated perception manifested in behaviour.

### RESEARCH THEMES



**Cells & Synapses**  
How neurons combine their inputs to produce an output signal for communication to other brain regions.



**Networks & Circuits**  
How the circuits underlying sensory processing & cognitive functions are formed and organised into large networks.



**Brain Systems**  
Coordination of activity across brain areas in real time by conducting parallel investigations in humans and animal models.

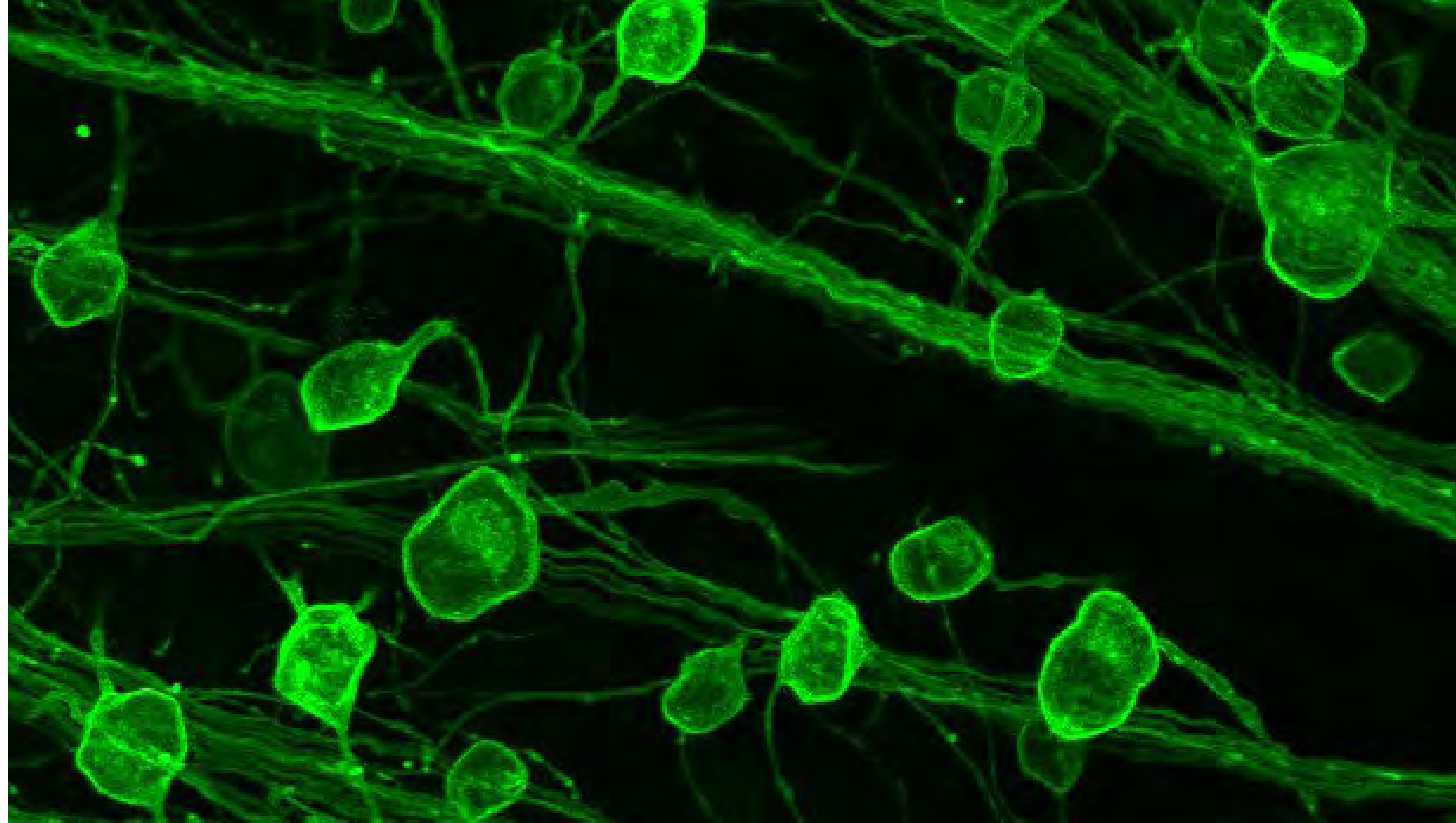


**Models, Technology & Techniques**  
Models (bayesian inference, predictive coding & error correction);  
Technology (computational, optical, electrical & biochemical);  
Techniques (behavioural, neuroimaging & electro-physiological)



# INTRODUCTION

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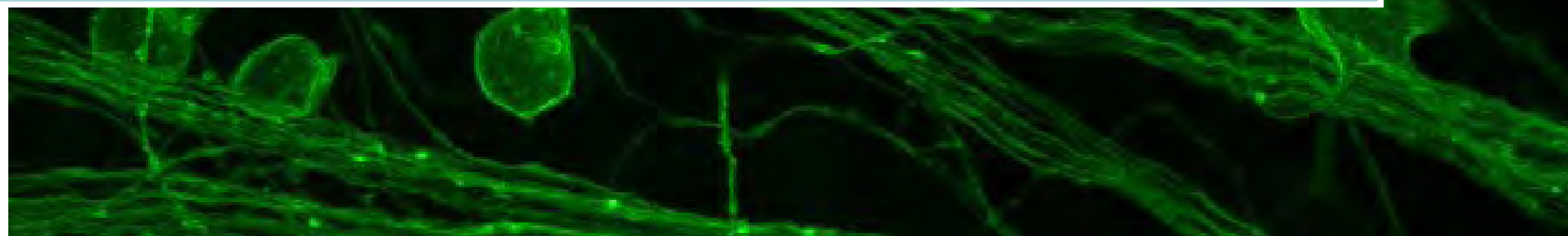
## Mission

By focusing on the complex brain functions that underlie attention, prediction and decision-making, Centre researchers are undertaking fundamental investigations into the principles of brain structure and function. The Centre is studying the relationship between brain activity and behaviour at multiple spatial and temporal scales, to build an integrated model of how attention, prediction and decision-making occurs. This is being accomplished by a research program based on four interconnected themes: Cells and Synapses, Networks and Circuits, Brain Systems and Models, Technologies and Techniques.

Our vision is to better understand how the brain interacts with the world.

## Strategic objectives

1. Reveal how the brain integrates information in large-scale networks to yield complex behaviour.
2. Develop neural technologies and translate them into patentable devices and software. Ensure that Australians benefit from the rapid advances being made in neurotechnologies.
3. Maximise dissemination and exploitation of research findings across the education, medical and government sectors, into industry, and across the broader community, to facilitate social change and progress.
4. Mentor a new generation of future leaders at the interfaces between neuroscience, physics, and engineering, to create an international competitive culture of combined theoretical and experimental neuroscience.
5. Position Australia amongst the world leaders in the international drive to expand the understanding of the brain. Serve as an Australian focal point for interactions with leading international neuroscience initiatives, including the Human Brain Project and the BRAIN initiative.





# INTRODUCTION

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## Director's message



During 2019 the Centre's research programs made further substantial progress towards achieving the scientific goals of the Centre. Scientists from the Cells and Synapses research theme are working to understand the morphology and the active and passive electrical properties of pyramidal neurons in the somatosensory cortex of rodents. Greg Stuart and his colleagues are particularly interested in the dendritic properties of pyramidal neurons which behave as synaptic targets of projections from the thalamus. Research led by Ulrike Grünert has identified non-classical ganglion cell types in the primate retina including their morphology, connections within the retina, and patterns of projection to the brain. Her team's work has provided new insights into the morphology and distribution of these retinal ganglion cell types. Michael Ibbotson and his colleagues examined why complex cells behave like simple cells, and how the response of some brain cells to visual scenes is caused by changes in the whole visual network, rather than in individual cells. This discovery is now helping researchers build more accurate models of brain networks.

The mammalian brain is assembled from local neural circuits that are connected into networks, in which signals are encoded as brief 'spikes' that communicate information between neurons and are the basis of computations performed in the brain. The Centre's Networks and Circuits researchers including Paul Martin and his team examined visual inputs and signal processing in thalamocortical loops to investigate predictive coding in attentional circuits. Pankaj Sah and his team have identified the neural substrates and circuits that drive top-down (attentional) components of fear learning and its extinction, and discovered a novel and dynamic learning-dependent

activity pattern in fear-related brain regions. Marta Garrido and her colleagues investigated the role of a putative subcortical pathway that links the thalamus and amygdala directly in rapid information processing of salient, attention-grabbing stimuli. Their discovery of a brain pathway that quickly transmits visual information settles a long-standing debate about its existence in humans and may help to explain the phenomenon of blindsight.

Research to understand the coordination of neural activity across brain areas in real time is undertaken by the Centre's Brain Systems researchers who conduct parallel investigations in humans and animal models. Marcello Rosa and his team examined neural signatures of decision-making in the primate cortex using multielectrode techniques to monitor how information encoded by trains of action potentials relate to an animal's behaviour, and how the information changes when certain parts of the relevant neural circuit are inactivated. Understanding human attention, prediction and decision-making using psychophysics, brain imaging and neural stimulation is the goal of Jason Mattingley and his colleagues. Their research characterised how stimulus information from the external environment is filtered on the basis of high-level cognitive sets for flexible and adaptive goal-directed behaviour.

Models, technologies and data analytical techniques are crucial to all aspects of the Centre's research. George Paxinos and his laboratory members have constructed a new generation of brain and spinal cord maps to assist scientists to navigate seamlessly between the central nervous system of humans and experimental animals. Their publication entitled, 'Human brainstem: cytoarchitecture, chemoarchitecture, myeloarchitecture', is the definitive high-resolution 3D-MRI atlas of the human brainstem. An international team led by Marcello Rosa has produced a cellular-scale connectome of the primate brain that is the first comprehensive publicly available digital map of the connections in a primate brain. Together with statistical 'data mining' techniques the connectome enables researchers to explore the network characteristics of the primate brain and gain new insights on how the brain works as an integrated system. Unified neural models for attention, prediction and decision including quantitative analysis of brain structure, function, and stimulation are the goal of Peter Robinson and his research team. Adopting a quantitative physical perspective that respects the main physical and biological characteristics of the brain has resulted in new insights and analytical approaches that are being made available as freely accessible software tools.

The 2019 Science Meeting program was organised by Centre Early Career Researchers Saba Gharaei and Elizabeth Zavitz, with the support and guidance of Centre Chief Investigators Jason Mattingley and Paul Martin. The meeting was held in December 2019 in Adelaide with the theme of 'How the Brain Interacts with the World'. The Science Meeting included sessions on plasticity,

vision and brain systems, sensation and perception, and vision and brain technologies. We were delighted to invite a number of senior researchers from outside the Centre including Professors Cliff Abraham, Stephen Williams, David McAlpine and Joes-Manuel Alonso to give keynote presentations.

The Centre's Early Career Researcher (ECR) activities in 2019 were again planned and implemented by the elected ECR Committee with support from the Central Theme. Whilst the Centre provides an unprecedented opportunity for ECRs to acquire multi-disciplinary brain research expertise, the Centre's ECR program ensures Fellows and Scholars are offered training and career development opportunities to foster career progression and their development as the next generation of leaders in brain research. Thanks to the 2019 ECR Committee members Molis Yunzab, Conrad Lee, Cong Wang and Marilia Menezes de Oliveira for their excellent work throughout the year. The Centre's strategic research initiatives program also enabled the Centre's ECRs and associate researchers to receive direct and indirect funding support for their Centre related research projects. The expansion of the Strategic Initiatives Project program to Associate Investigators was again highly beneficial, with further projects approved in 2019 to fund multidisciplinary research projects driven by Centre ECRs and Centre Associate Investigators.

The Brain Dialogue is the Centre's public engagement platform that publishes 'Discovery' pieces online to highlight research outcomes. The Dialogue uses 'In A Nutshell' single-sentence summaries, 'Big Picture' translations that explain each paper and its significance in lay English, and 'Next Steps' to encourage further exploration by viewers. The Discovery pieces are managed by the Centre Communications Officer, Merrin Morrison, and viewed by the Brain Dialogue's social media followers which include the world's top journals and news outlets. With a combined following of over 3,500 users, the Brain Dialogue's content was viewed 135,000 times by over 10,500 unique users throughout 2019.

As in previous years, the Centre's Neuroethics Program led by Adrian Carter continued to be an outstanding success with major activities held in late 2019. The Neuroethics Program in conjunction with the Australian Neuroethics Network and Monash University organised the public event 'Brain Control: The impact of science and technology on our mental health, law and privacy' held in Melbourne in December in conjunction with the 'Neurofutures: Neuroscience and Responsibility' two-day conference. The Neuroethics program also published a highly viewed article in The Conversation in 2019 on the current state of neurotechnology regulation.

My sincere thanks to Prof Lyn Beazley AO, Chairperson, and to all of the Centre Advisory Board members for their ongoing

commitment to provide oversight and guidance to myself regarding the Centre's research and other programs. I would like to extend my thanks to the Centre's Executive who continue to provide incisive scientific critical analysis of the Centre's research activities, as well as advice and support for the Centre Leadership team. My particular thanks to the Centre's Chief Operating Officer, Dr Glenn Papworth, and the Central Theme team for their outstanding support for all of the Centre's activities. Their expertise and highly efficient administrative support at each of the Collaborating Organisation nodes enables the Centre to operate smoothly and fulfil all of our reporting and compliance responsibilities. I know the Centre researchers greatly appreciate the Central Theme team's efforts to minimise their administrative burden.

During 2019 we continued our planning to provide sustained support for the current educational, public outreach, and community engagement by the Centre after the current funding ceases. The Centre's established collaboration and administrative processes provide an excellent foundation upon which to sustain the Centre's programs beyond 2021. We have made arrangements with the Australasian Neuroscience Society to support the Australian Brain Bee Challenge (ABBC) for a further two years. I would particularly like to thank Ramesh Rajan for his enthusiastic and tireless efforts over the past four years as Director of the ABBC.

The 2019 Annual Report describes how the Centre of Excellence for Integrative Brain Function has once again exceeded the ARC's key performance indicators for outstanding neuroscience research, development of the next generation of neuroscience researchers, and impactful and energetic engagement with our community and society. I do hope you enjoy reading this year's report.

*Gary F Egan*

Professor Gary Egan, Director



## Message from the Chair



“In 2019 the Centre continued to produce research outputs giving insight into the mechanisms of integrative brain function. I would like to thank all of the Centre’s researchers, staff, PhD students, post-doctoral research fellows and supporters for their outstanding efforts and wonderful contributions during 2019.”

The ARC Centre of Excellence for Integrative Brain Function is a highly multi-disciplinary research centre addressing the question of how the brain interacts with the world. The Centre’s researchers investigate brain activity at multiple scales of the brain in order to understand how neural processes associated with attention, prediction and decision making are integrated and manifest in higher cognition and, ultimately, behaviour.

In 2019 the Centre continued to meet this significant challenge and has continued to produce research outputs giving insight into the mechanisms of integrative brain function. In 2019 I was again pleased to see the continued upward trend of number of scientific publications and number of citations by Centre researchers, reflecting the quality and, importantly, the impact of the science. Centre researchers presented plenary and keynote addresses at international meetings, highlighting the unique strengths of the Centre’s collaborative and multiscale research program into the principles of integrative brain function.

In 2019, as in previous years, the passion shown by our early career researchers was evident not only in their research efforts, but in their contribution to the Centre’s education and outreach programs. The Centre’s young neuroscientists volunteered to travel to primary schools around the country to present awards to those children who won the Centre’s national annual brain art competition. I commend them for their work in giving the winning primary school students an interactive and exciting lesson about the brain. This is truly a terrific example of the dedication and commitment by the Centre’s Early Career Researchers to promote neuroscience and foster the next generation of brain researchers.

Important initiatives continue to be undertaken both within the Centre and in events we organised in the research and broader communities. As a Centre, we have a responsibility to ensure that we support and represent our researchers and members equally, regardless of their gender, ethnicity, religion, personal preferences or identity, and ensure that we address systemic barriers to equity and diversity. The Gender, Equity and Diversity Committee’s work is ensuring the Centre is in the vanguard to promote equity and diversity within the Australian brain research community. Training on diversity and inclusiveness

has continued in 2019 with a particular focus on unconscious bias and inclusive leadership. The Centre’s leadership team continues to recognise the personal challenges and pressures of being a researcher, and in particular the difficulties faced by those researchers for whom English is not their first language. The early career researcher group with the support of the Centre’s Executive has again promoted the development of workshops and shared resources to help address these challenges.

Thank you once again to my fellow Centre Advisory Board members for their inspiring commitment to continue to provide governance, support and advice for the Centre. The combined experience of the Board in scientific research nationally and brain science globally, as well as in broader cultural and financial issues, is a wonderful resource for the Centre. The passion and experience the Board have brought to the Centre’s education, outreach and non-research programs over the years, is particularly energising to all.

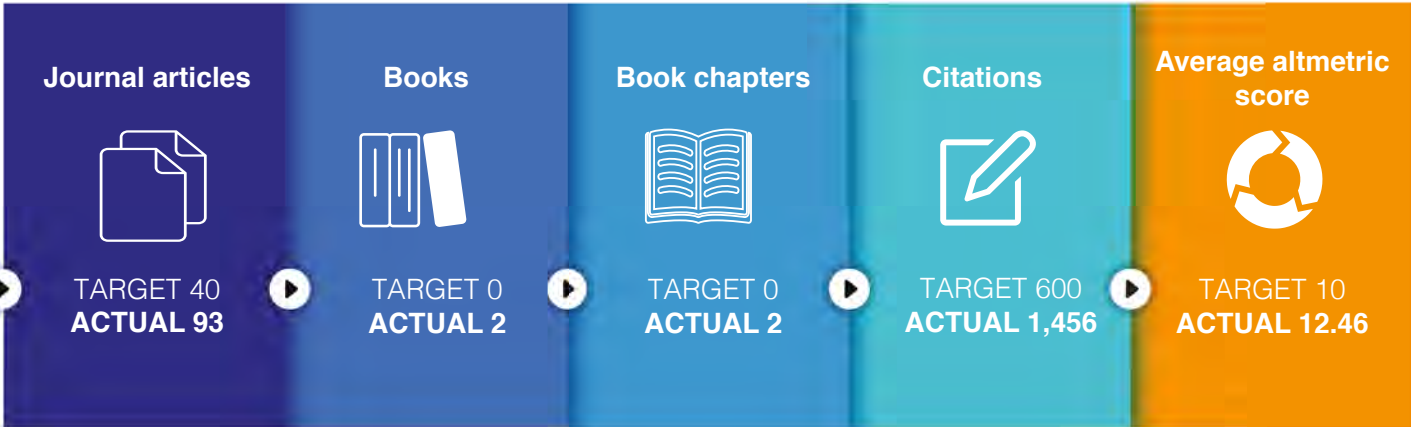
I would like to thank all of the Centre’s researchers, staff, PhD students, post-doctoral research fellows and supporters for their outstanding efforts and wonderful contributions during 2019. Thank you in particular to the Centre’s Director, Professor Gary Egan, for his inspired leadership of the Centre, and to the Centre’s Chief Operating Officer Dr Glenn Papworth and the Central Theme administrative team for their tireless work and dedication to achieving the Centre’s goals.

I am greatly looking forward to learning about the Centre’s achievements throughout 2020 which I am sure will result in further significant contributions to our understanding of how the brain interacts with the world.

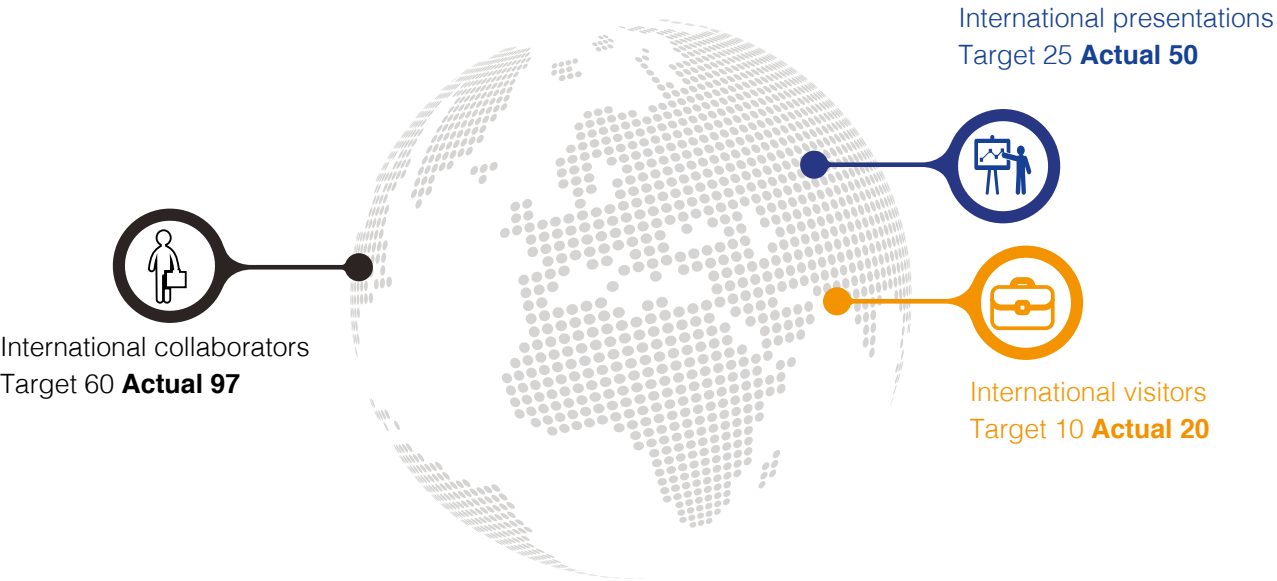
Professor Lyn Beazley AO



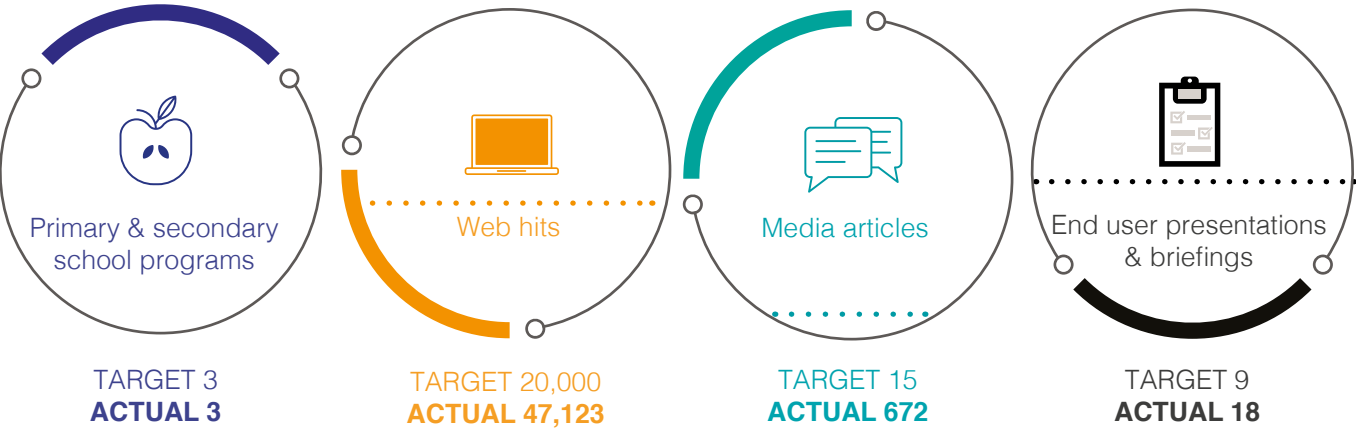
2019 Research Output and Impact



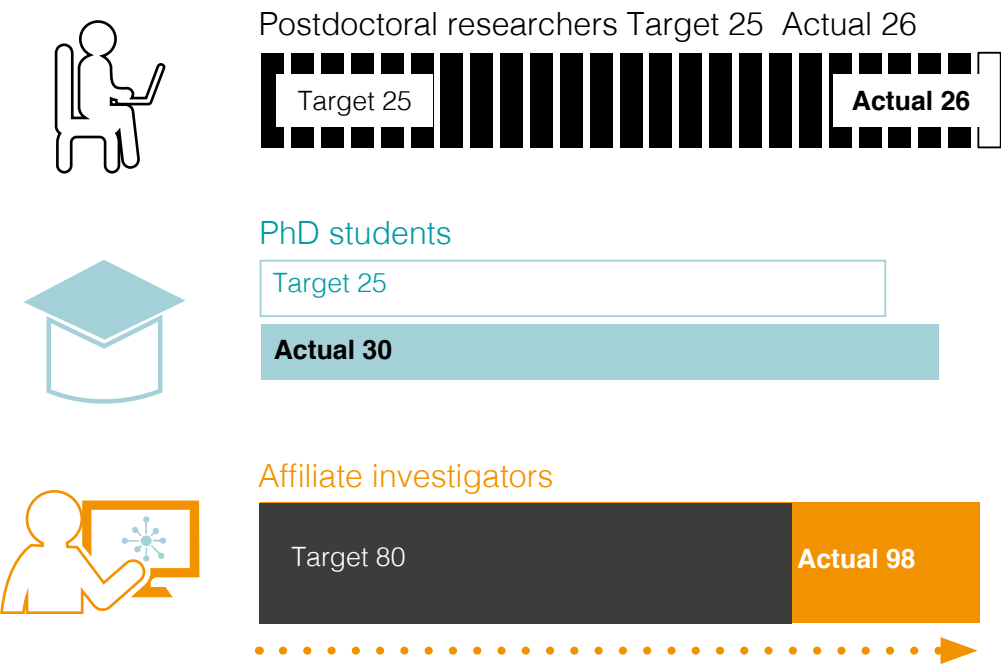
International Profile



Community



Personnel



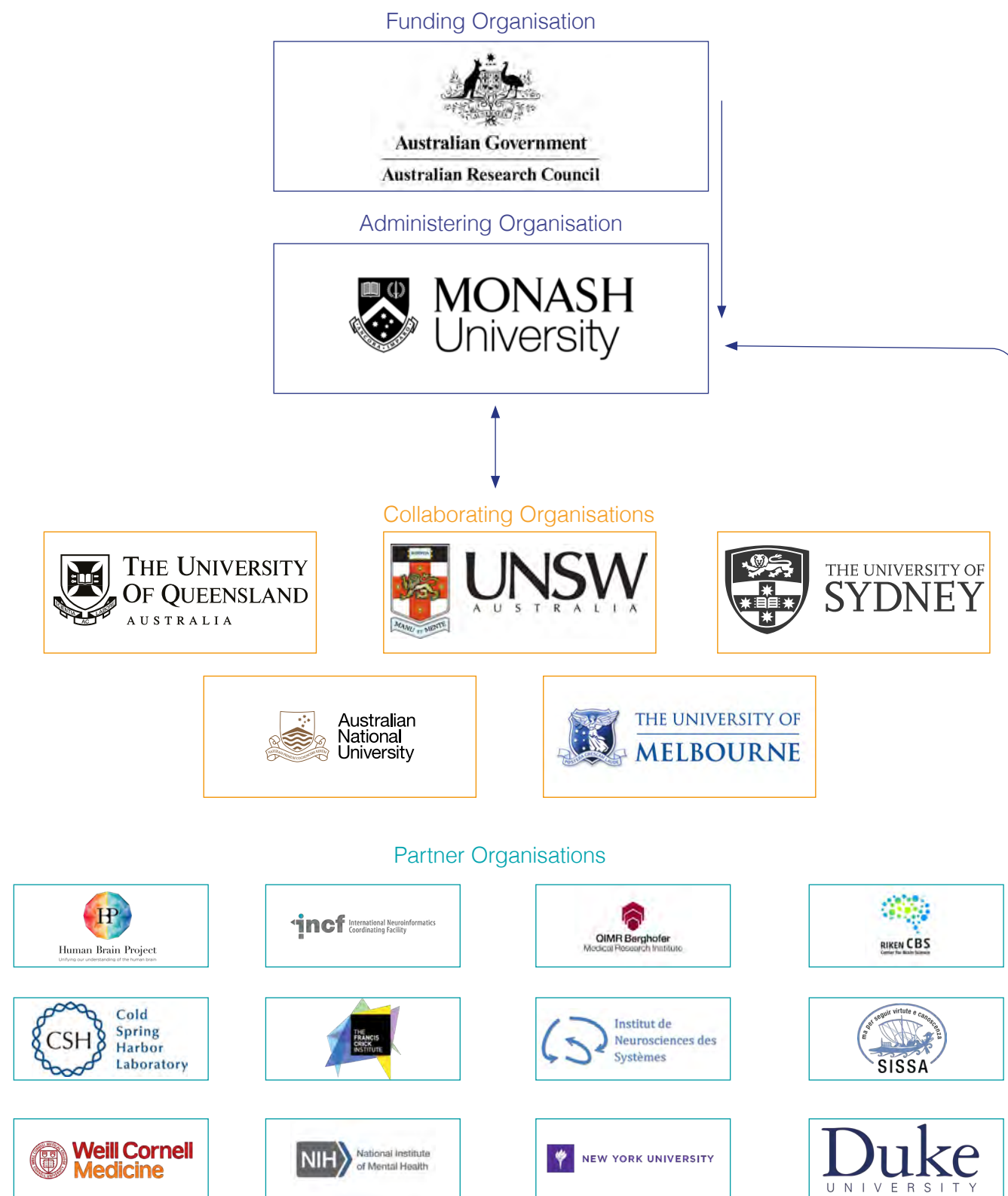


# INTRODUCTION

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## Centre Structure

The Brain Function CoE is funded by the Australian Research Council with contributions from six universities across Australia, one Australian partner organisation and 11 international partner organisations.



## Governance

The Advisory Board provides strategic direction and advice regarding all aspects of the Centre's activities to the Director, and is comprised of Australian and international members of the neuroscience and broader research community. The Board meets a minimum of twice per year – both in person and virtually, and participates in the Centre's annual scientific meeting.

Advisory Board members have significant experience in collaborations involving multiple large organisations, as well as international research activities, industry, and government engagement.

### Advisory Board Members:

- Prof Lyn Beazley, Chair, Past Chief Scientist of Western Australia
- Dr Amanda Caples, Lead Scientist, Victorian State Government
- Prof John Funder, Senior Fellow, Hudson Institute of Medical Research
- Prof David van Essen, Director, Human Connectome Project
- Prof Ulf Eysel, Principal Investigator, Department of Neurophysiology, Ruhr University, Bochum, Germany
- Dr Allan Jones, President and CEO, Allen Institute, Seattle, USA
- Dr Jeanette Pritchard, Executive Officer, The Garnett Passe and Rodney Williams Memorial Foundation
- Dr Stella Clark, Executive Director, Stella Connect Pty Ltd



Advisory Board members at the annual meeting held in Adelaide.  
L-R: Glenn Papworth, Amanda Caples, Gary Egan, Lyn Beazley, Ulf Eysel, Stella Clark, JohnFunder, Hatice Sarac (administrator) and Jeanette Pritchard

# INTRODUCTION

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## Senior Leadership

Centre Director Professor Gary Egan oversees the Centre’s research and operations while playing a key role in the development of industry engagement activities. Deputy Director Professor Marcello Rosa is instrumental in the development of international collaborations and partnerships and acts as an alternate for Professor Egan. Associate Director Professor Jason Mattingley plays a critical role in the strategic development of key initiatives in the Education and Training Program and acts as an alternate for Professor Rosa.

## Executive Committee

The Executive Committee oversees the Centre’s operations and comprises representatives from each research theme, collaborating institution and senior Centre personnel. In 2019, the Executive Committee met monthly and comprised:

- Prof Gary Egan, Director, Brain Function CoE, Monash University
- Prof Marcello Rosa, Deputy Director, Brain Function CoE, Monash University
- Prof Jason Mattingley, Associate Director, Brain Function CoE, Brain Systems, University of Queensland
- Prof Pankaj Sah, Neural Circuits, University of Queensland
- Prof Greg Stuart, Cells and Synapses, Australian National University
- Prof Peter Robinson, Models, Technologies and Techniques, University of Sydney
- Prof Michael Ibbotson, University of Melbourne
- Prof George Paxinos, University of New South Wales
- Dr Glenn Papworth, Chief Operating Officer, Monash University (ex officio)

## Administrative Team – Management and Operations

The Administrative Team is comprised of administrative and management personnel providing support to the Director and Executive Committee in the conduct, communication and administration of research. Personnel are located at each of the collaborating organisations throughout Australia, and meet monthly to review, plan and conduct activities across the Centre.

Central Theme staff, which includes the Director and Chief Operating Officer, are based at Monash University, and are responsible for managing and overseeing Centre finances and ensuring the effective collection and reporting of project information according to timeframes, deliverables and key performance indicators. The Central Theme also undertakes special projects at the request of the Director to pursue new opportunities to maximise the scope, reach or impact of the Centre. Central Theme staff organise both internal and external activities and programs, including development, training, media and communications, industry engagement, education and public outreach.

“In addition to scientific research, the Centre has developed non-research programs aimed at interacting with the enduser community. These programs are spearheaded by coordinators to address societal, ethical, educational, computational and industry matters raised by brain research.”

## Program Coordinators

In addition to scientific research, the Centre has developed non-research programs aimed at interacting with the end-user community. These programs are spearheaded by coordinators to address societal, ethical, educational, computational and industry matters raised by brain research.

- A/Prof Adrian Carter, Neuroethics Coordinator
- Prof Melinda Fitzgerald, Chair, Gender, Equity and Diversity Committee
- Dr Pulin Gong, Neuroinformatics Coordinator
- Dr Wojtek Goscinski, Neuroinformatics Coordinator

## Early Career Researcher Committee

The Centre continues to support early career researchers (ECRs), including PhD students, by offering professional support, development and a mentorship program. The ECR committee manages the budget allocated by the Centre, attends monthly Zoom teleconferences, reviews and distributes travel award applications and organises the annual ECR retreat, Science meeting workshops and other professional development opportunities for the Centre ECRs.

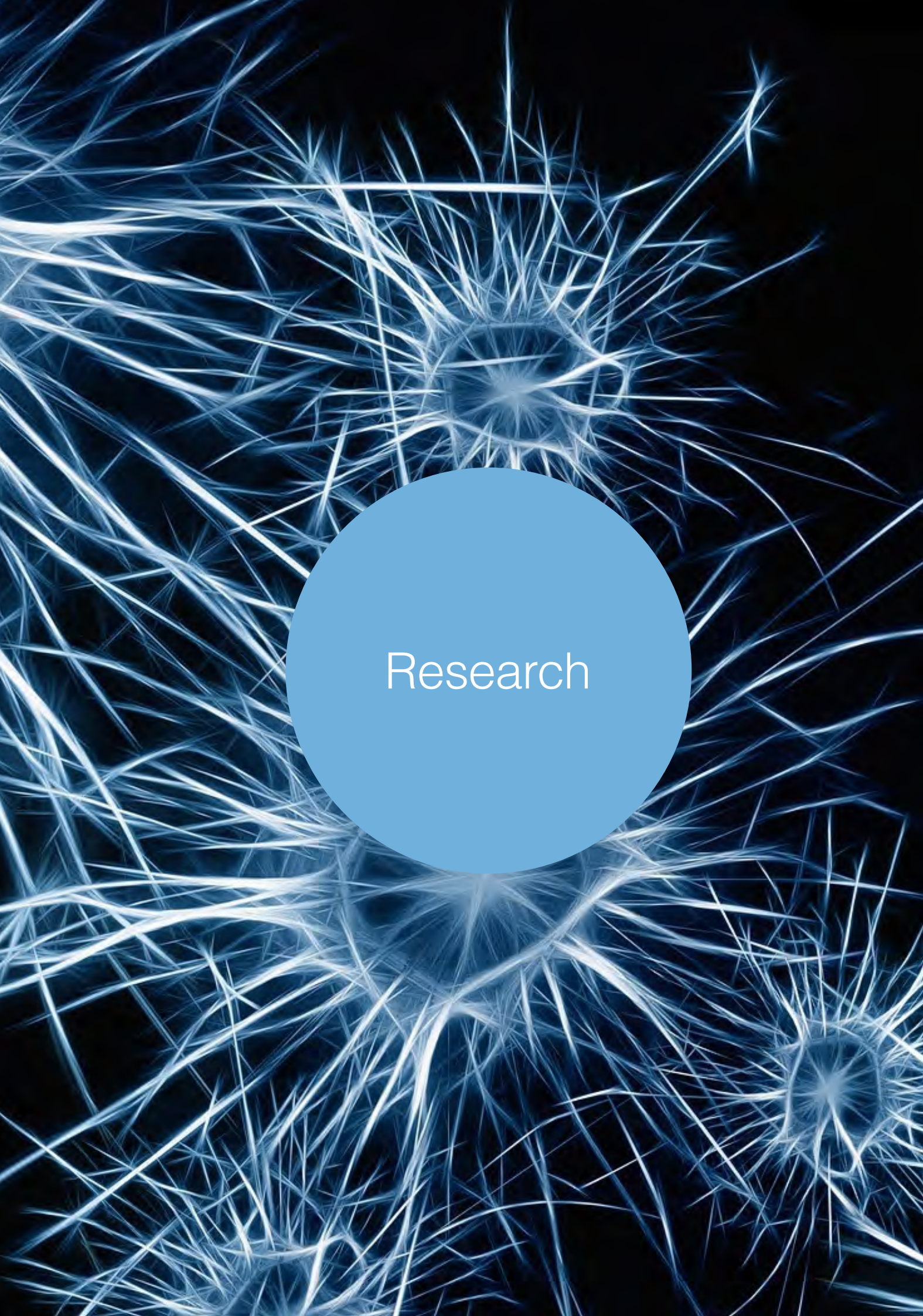
The 2019 ECR committee representatives were

- QLD: Cong Wang
- NSW: Dr Marilia Menezes de Oliveira
- ACT: Dr Conrad Lee
- VIC: Dr Molis Yunzab



2019 ECR Executive Committee L-R: Conrad Lee (ACT), Cong Wang (QLD), Molis Yunzab (VIC) and Marilia Menezes de Oliveira (NSW).





Research

# RESEARCH REPORT

cells & synapses • networks & circuits • brain systems • models, technologies & techniques

## Research program

The Centre's research program spans different levels of analysis, organised into the themes of Cells & Synapses, Networks & Circuits, Brain Systems, and Models, Technologies & Techniques.

Coordinated investigations are undertaken across the research themes at different spatial scales using theoretical, experimental, analytical, and modelling approaches.

The research program of the Centre is structured to allow our researchers to work on unique, multi-scale approaches to address the three key integrative brain functions of Attention, Prediction and Decision.

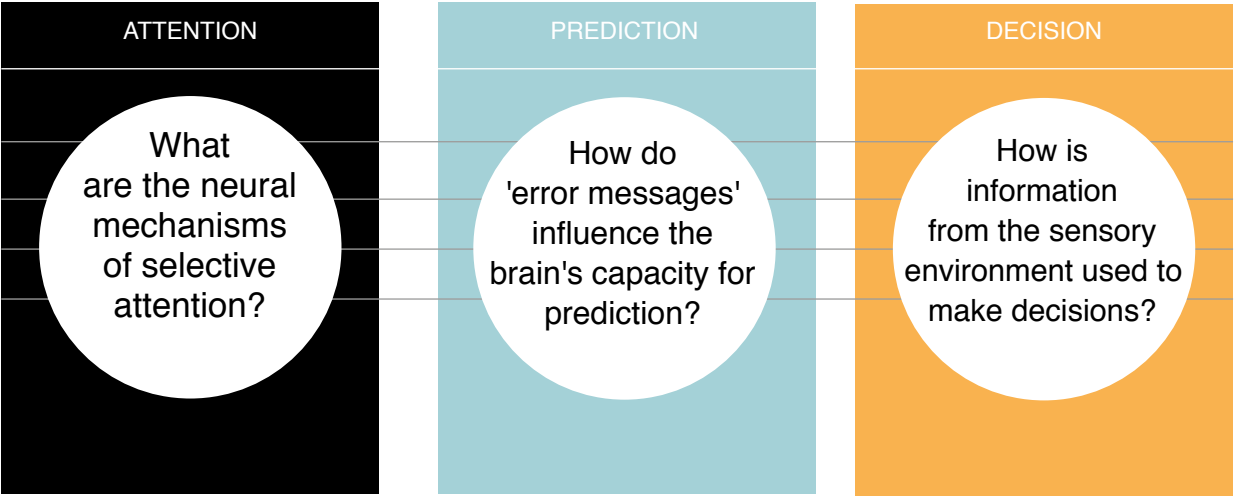
The research program is addressing the following critical cross-theme research questions:

- ATTENTION - What are the neural mechanisms of selective attention?
- PREDICTION - How do error messages influence the brain's capacity for prediction?
- DECISION - How is information from the sensory environment used to make decisions?

In 2019 this approach has further developed the collaborative multi-scale research projects that have grown between research groups at different Centre nodes.

Following is a summary of the progress and outcomes of a key selection of projects undertaken in 2019.

Cells & Synapses  
Networks & Circuits  
Brain Systems  
Models, Technologies  
& Techniques



These three critical research questions guide our investigations of the integrative brain functions of Attention, Prediction and Decision. Coordinated investigations are being undertaken across the Research Themes at three different spatial scales using theoretical, experimental, analytical, and modelling approaches.



# RESEARCH REPORT

cells & synapses • networks & circuits • brain systems • models, technologies & techniques

## Cells & synapses

Brain function relies on spiking activity under control of sensory inputs and stored brain states (memories). However, spiking activity also depends on the biophysical properties of neurons and their connections (synapses), as well as whole brain (behavioural and hormonal) states. Ultimately, the generation of spikes requires the movement of charged ions.



### Distribution and function of inhibitory interneurons in the cortex as a function of age

Investigators: George Paxinos, Pankaj Sah, Marcello Rosa, Teri Furlong, Roger Marek, Cong Wang, Nafiseh Atapour, Sam Merlin

As cortical processing reflects the interplay between excitation and inhibition, knowledge of the heterogeneous distribution of subtypes of interneurons and pyramidal within cortex is necessary to understand cortical function. Further, as ageing affects cognition and overall levels of cortical inhibition, it is of interest to determine how the distribution of interneurons, and thus their effects on cognition, is altered by age. Understanding the consequences of damage/inactivation of inhibitory cells may allow us to mimic the effects of ageing in the cortex. This project examines the functional role of prefrontal cortex in cognition, with the goal of manipulating these neurons during behaviour.

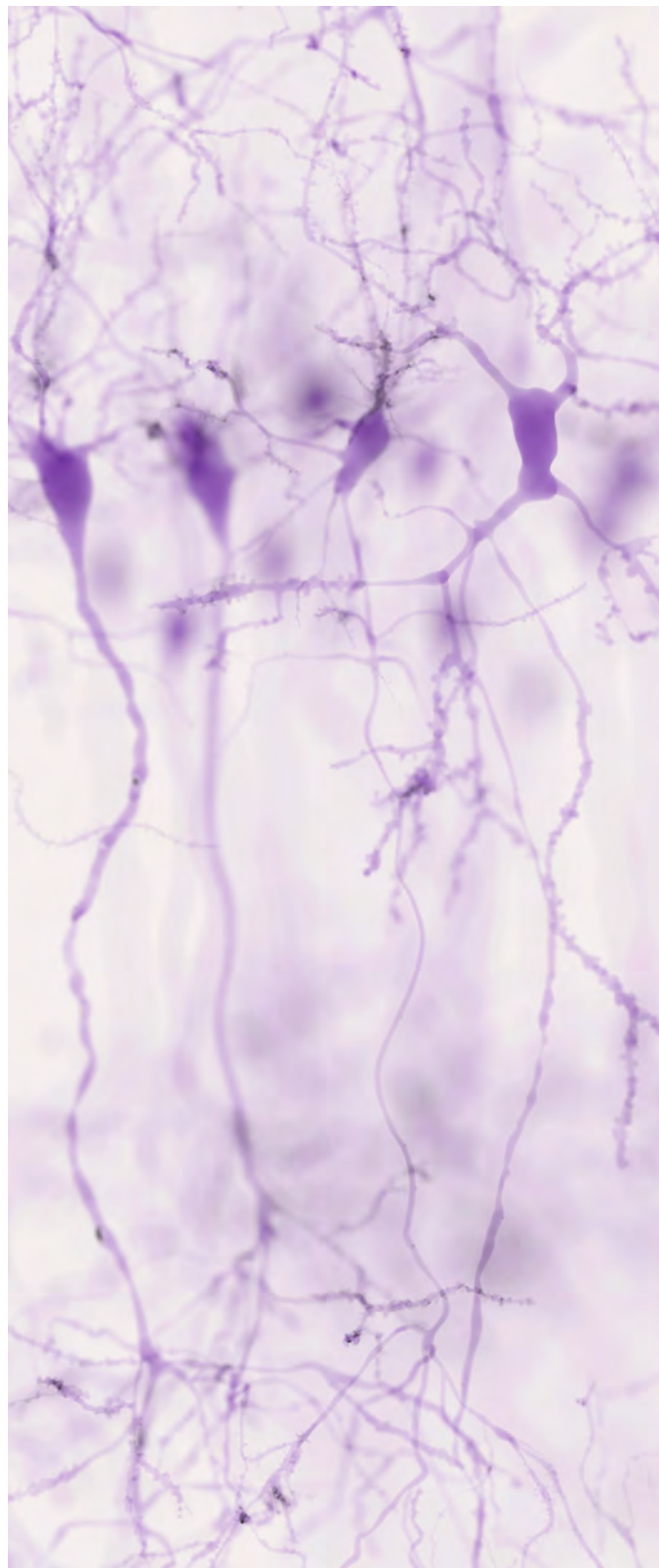
Pilot data laying the foundation for this study has used electrophysiological recordings from prefrontal cortex (PFC) neurons, to determine if they are active during the cognitive task, known as novel object recognition (NOR). In addition, immunohistochemistry has been performed for the neuronal activity marker, c-Fos, to identify the precise site of activity (and the type of neuron involved, eg., parvalbumin or somatostatin-expressing neurons).

We have demonstrated using real-time electrophysiological recordings that the PFC of rats is active when a familiar object is explored compared to when no object is present in the environment. This finding suggested that PFC has a role in recognition memory. Further, the PFC is more active when a novel object is explored compared to a familiar object. A similar pattern of recordings was also found for the hippocampus. Further, we also demonstrated that c-Fos is up-regulated in PFC when a novel object is explored compared to a familiar object. Together these findings suggest that the PFC (and the hippocampus) have a role in processing and/or recognising novelty.

#### Next steps

To explore whether c-Fos is in parvalbumin neurons or not (the preliminary mouse data suggests that it is not- and is instead located in excitatory neurons, which confirms the 'sorting data' obtained from the electrophysiological recordings that interneurons may not be active during this task). The Sah group will also use optogenetics to silence the hippocampal to PFC projection during NOR to establish whether these brain regions interact to drive object recognition.





## Dendritic spikes in apical obliques of L5 pyramidal neurons

Investigators: Vincent Daria, Greg Stuart, Michael Castanares

This project aims to understand the morphology, as well as the active and passive electrical properties of pyramidal neurons in somatosensory cortex of rodents. We are particularly interested in the dendritic properties of these neurons (specifically apical oblique dendrites) which behave as synaptic targets of projections from the thalamus.

Using a combination of electrophysiology, two-photon calcium and voltage imaging in cortical Layer 5 pyramidal neurons, this project explores whether these oblique dendrites are capable of generating regenerative dendritic events that can potentially boost forward- or backward- propagating signals.

Preliminary modelling data shows a step-wise increase in calcium influx specific to: (1) oblique dendrites with ~1-micron diameter; and (2) obliques that show strongly attenuated first back-propagating action potentials (bAPs). Using a multi-compartmental model of a L5 pyramidal neuron, we describe a condition where there is a non-linear rise in the membrane potential following a train of two bAPs. The non-linear rise in the Ca2+ response is concentrated at apical obliques situated about 100microns from the soma, but not found at proximal and distal obliques where they exhibited a linear increase in Ca2+ transients. The Ca2+ spikes at the obliques occurs at a more physiologically lower frequency of 20-30Hz, suggesting that oblique dendrites can potentially function as active sub-integration sites at a slower somatic activity way before Ca2+ spikes at the nexus are generated, providing novel insights into the role of these dendrites in synaptic integration.

### Next steps

We will investigate the morphology, as well as the active and passive electrical properties of cortical pyramidal neurons in both human and non-human primates, and compare this to what is known about the properties of pyramidal neurons in somatosensory cortex of rodents.

## Identifying non-classic ganglion cell types in primate retina

Investigators: Ulrike Grünert, Paul Martin, Marcello Rosa, Sammy Lee, Subha Nasir-Ahmad, Rania Masri, Ashleigh Chandra.

The retina contains at least 20 morphological types of ganglion cells which are involved with distinct visual pathways, yet only six of these ganglion cell types are well understood. It is thought that at least 10 unique cells are yet to be discovered, potentially projecting to subcortical brain centres involved in rapid detection of environmental threats and opportunities, specifically processing information from the peripheral visual field.

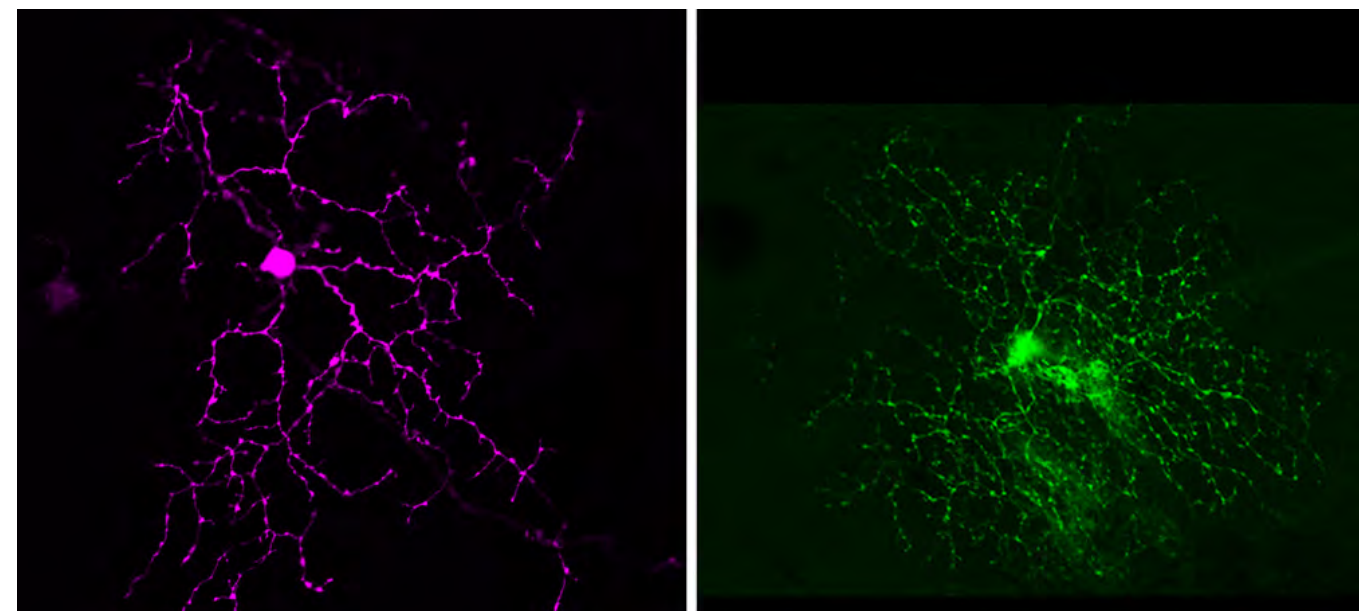
Our aim is to develop a greater understanding of these cell types, their morphology, their connections within the retina, and their patterns of projection to the brain. We're using molecular markers and intracellular injection in marmoset and macaque retinas, which allows us to further our understanding of retinal cell types and their inputs to brain circuits for attention.

The molecular markers tested have revealed specific labeling of wide-field type ganglion cells that project to attention-regulating brain centres. Our research has distinguished at least 17 types of ganglion cell, including midget, parasol, broad thorny, small bistratified, large bistratified, recursive bistratified, recursive monostratified, narrow thorny, smooth monostratified, large sparse, giant sparse (melanopsin) ganglion cells, and a group that may contain several as yet uncharacterised types.

Our research has provided new insights into the morphology and distribution of previously poorly understood retinal ganglion cell types.

**Next steps:** to further explore the function role and connectivity of retinal ganglion cells in marmoset and macaque retina.

**Featured publication:** Masri, R.A., Percival, K.A., Koizumi, A., Martin, P.R., Grünert, U. (2019). Survey of retinal ganglion cell morphology in marmoset. *J Comp Neurol*, 527(1), 236-58.



Retinal ganglion cells projecting to the inferior pulvinar (left) and the superior colliculus (right), Kwan et al., 2019.



# RESEARCH REPORT

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## Contrast-dependent shifts in mouse V1 cells: an intracellular study

Investigators: Michael Ibbotson, Molia Yunzab, Hamish Meffin, Shaun Cloherty

Neurons in mammalian visual cortex (V1) are typically classified as either simple or complex on the basis of their responses to visual stimuli. Previous studies using extracellular recordings have shown that the responses of complex cells become more simple-cell-like at lower stimulus contrasts, suggesting more flexibility in V1 processing mechanisms than previously thought.

This contrast-dependent change could arise either from differences in the inputs of neurons or from differences in the intrinsic properties of neurons. We performed the intracellular study to determine which of these mechanisms accounts for the contrast-dependent changes in complex cells.

To understand the synaptic basis for this shift in behaviour, we used in vivo whole-cell recordings of anaesthetised mice while systematically shifting stimulus contrast. Using this technique we have found that contrast levels do not change the biophysical response properties of neurons, whereas the inputs to neurons were contrast-dependent. Our results reveal that contrast-dependent changes in V1 cell responses arise from network activity rather than intrinsic properties.

### Next steps

We plan to anatomically identify the V1 neurons with contrast-dependence through intracellular dye injections and imaging.



### IN A NUTSHELL:

## Why complex cells behave like simple cells

**A switch in how some brain cells respond to visual scenes is caused by changes in the whole network, rather than in the cells themselves.**

One of the major brain regions responsible for making sense of what we see is called the primary visual cortex, or V1. There are two types of cells in V1: simple and complex. Simple cells have a simple receptive field – that is, they become active only in response to stimuli in specific areas within our field of vision. Complex cells have a much more complex receptive field, responding to visual stimuli in many different locations.

In some situations, however, complex cells can behave like simple cells. This can happen when we look at a scene with low contrast between different elements, like when driving in snow with low visibility.

To understand this shift in brain cell behaviour, Brain Function CoE investigators Molis Yunzab, Hamish Meffin, Shaun Cloherty and Michael Ibbotson, along with a team of collaborators, studied V1 responses in mice.

The researchers measured the activity of individual cells within the brain while a mouse viewed a screen showing different patterns. The contrast of the patterns was varied to see how this affected the response of simple and complex cells in V1.

The researchers found that the switch from complex cells to simple cells when viewing low-contrast patterns is not a result of specific changes within individual brain cells. Instead, the switch is due to a change in the whole network of brain cells, which is caused by the altered visual inputs. This result shows that the activity signature of V1 complex cells – in other words, whether they behave like simple or complex cells – is not completely fixed but depends to some degree on the activity of the whole network.

This discovery could help researchers to build more accurate models of brain networks, which can be used to study how the brain works.

### Next steps

**The researchers hope to learn more about the brain cells involved in the environment-dependent network changes. This information will help them to link the cells' function and location in the brain with the network's activities.**

### Reference

Yunzab, Mw., Choi, V., Meffin, H., Cloherty, S.L., Priebe, N.J., & Ibbotson, M.R. (2019). Synaptic basis for contrast-dependent shifts in functional identity in mouse V1. *eNeuro*, 6(2), ENEURO.0480-18.2019. doi: 10.1523/ENEURO.0480-18.2019

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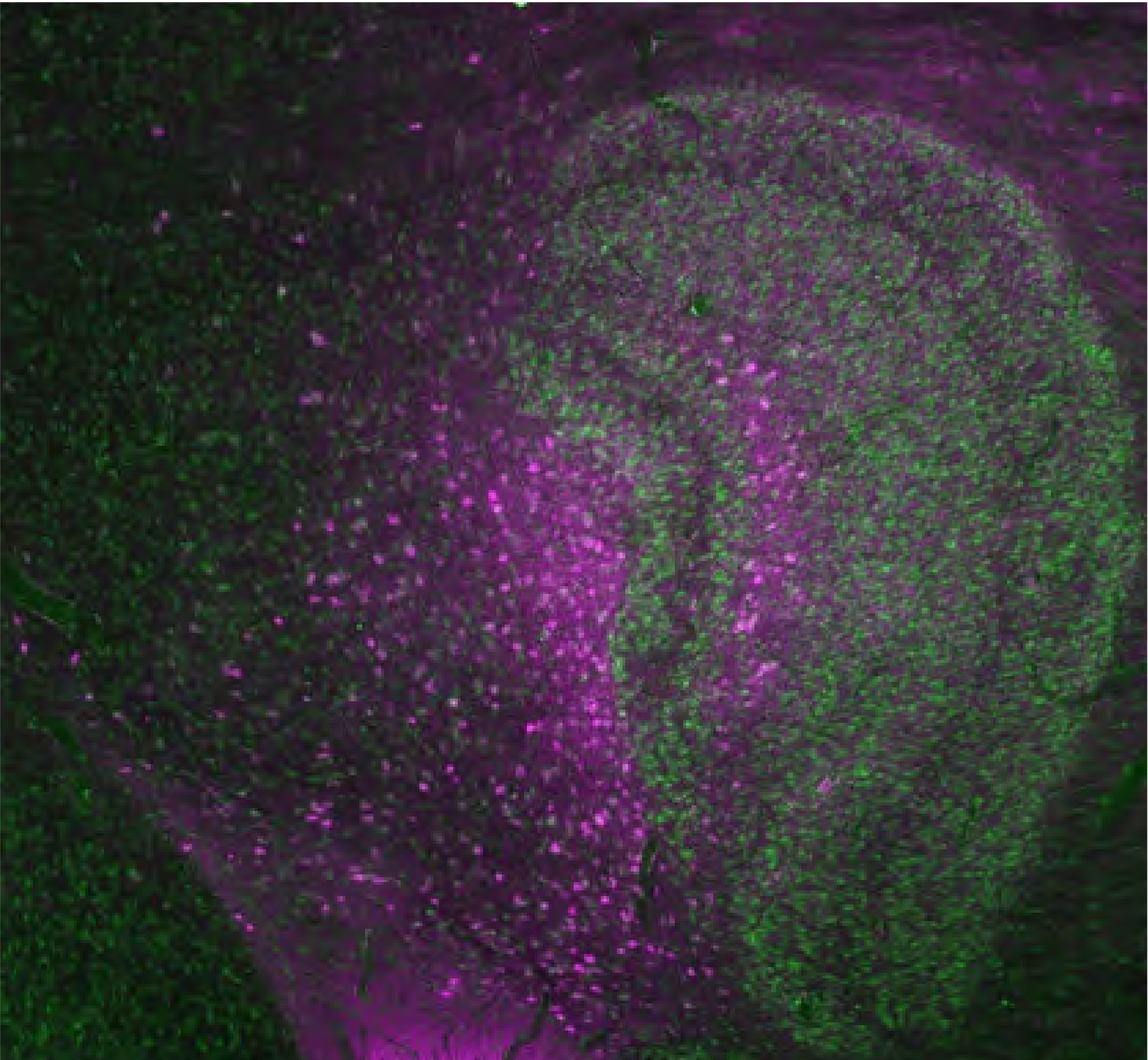


# RESEARCH REPORT

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## Networks & circuits

The mammalian brain is assembled from local neural circuits that are connected into networks, in which signals are encoded as brief voltage ‘spikes’. This spiking activity is used to communicate information between neurons, and is the basis of the computations performed in the brain.



### Visual inputs and signal processing in thalamocortical loops; predictive coding in attentional circuits

Investigators: Paul Martin, Ulrike Grünert, Marcello Rosa, Pulin Gong, Partha Mitra, Natalie Zeater, Calvin Eiber, Alexander Pietersen, Elissa Bellucini, Brandon Munn, Xian Long

This multi-discipline project uses anatomical tracing and array recordings of thalamic reticular and lateral geniculate nucleus (LGN) to look at brain circuits for alertness and attention. Linking neural circuits and modelling, this group explores the eye inputs, physiology and anatomy in visual pathways between thalamus and cortex.

Turbulence physics methods have been applied to LGN and cross correlated with cortical regions (V1 and MT), in order to analyse differential connections of LGN to V1 and MT. In addition, multichannel neural recording systems have been established that simultaneously track multiple cells and field potential ‘brain wave’ activity in thalamus and cortex. This platform has enabled the functional links between these brain regions to be analysed and tested against predictive coding models of brain function. Preliminary array recordings have also been made in the visual pulvinar nucleus, a poorly-understood region of the thalamus considered important for attentional modulation and rapid responses to environmental threats and opportunities. Projections of retinal output neurons (ganglion cells) to pulvinar have also been characterised. Initial results indicate complex motion-processing properties consistent with rapid detection of approaching visual threats.

Micrographs of sections through the LGN and inferior pulvinar revealing calbindin labelling (magenta) of the pulvinar and the koniocellular layers, Huo et al., 2019.

**Next steps**  
The next big step for this project is to understand how the two eye inputs are combined in attentional circuits to analyse the distance and movement of visual threats and opportunities.

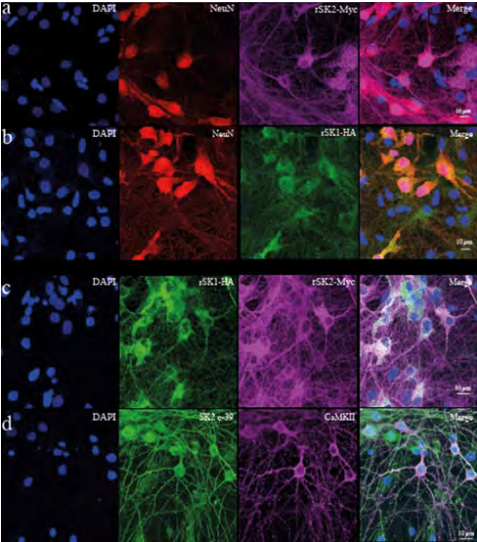
**Featured publication**  
Munn, B., Zeater, N., Pietersen, A.N., Solomon, S.G., Cheong, S.K., Martin, P.R., Gong, P. (2020). Fractal spike dynamics and neuronal coupling in the primate visual system. *J Physiol*, doi: 10.1113/JP278935.

# RESEARCH REPORT

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## Neural circuits that mediate fear learning and extinction

Investigators: Pankaj Sah, Roger Marek, Madhusoothanan Bhagavathi Perumal, Lei Qian, Yajie Dun, Robert Sullivan, Cong Wang



This project focuses on the investigation and identification of neural substrates and circuits that drive top-down (attentional) components of fear learning and its extinction. In our rodent models, we use classical (Pavlovian) conditioning, a well-established fear learning paradigm that is preserved amongst species, including humans. This paradigm has two components to it. Firstly, fear learning in which subjects learn to associate a neutral stimulus (such as a tone) with an aversive one such as a footshock. As a result, the animals learn that the previously neutral tone now predicts an aversive outcome, which is reflected in a fear response such a freezing or fleeing. However, further repetitive exposure to the same tone

alone will eventually cause the animals to reassociate the stimulus to not being fearful any longer, a learning referred to as extinction. Extinction is thought to be, at least in part, a form of new learning, which is highly context-specific. This is the reason why the fear can relapse even after extinction, a phenomenon that affect patients suffering from anxiety disorders.

The key brain structures to fear and its extinction are the hippocampus, prefrontal cortex and amygdala. To study these behaviours, electrophysiological approaches (in vitro and in vivo) combined with behavioural testing while manipulating circuits between these structures using chemogenetic and optogenetic tools, have been applied. This approach allows us to study the intrinsic neural circuits within each of these structures, and the connections between them. Moreover, it also allows us to manipulate neural circuits that underlie large-scale neural network activity to drive the behaviour, which is in line with a key objective of the centre.

Recent investigations of neural activity during fear learning and extinction have identified a novel and dynamic learning-dependent activity pattern in these fear-related brain regions.

### Next steps

We plan to anatomically identify the V1 neurons with contrast-dependence through intracellular dye injections and imaging.

### IN A NUTSHELL:

## Understanding SK1, a channel protein that doesn't act like a channel protein

**Researchers have discovered the role of a protein in rat brain cells that does not behave as expected.**

Cells in the brain communicate with each other by sending and receiving electrical signals. This activity transmits information from one brain region to another, which enables the brain to carry out its various functions.

Brain cells make different types of proteins that affect their electrical behaviour. One group of proteins, called small-conductance calcium-activated potassium channels (SK channels), helps to control the movement of electrically charged molecules across the cell membrane. When the concentration of calcium inside a brain cell reaches a certain level, SK channels are activated, allowing potassium to cross from the inside of the cell to the outside. This reduces the cell's electrical activity, decreasing the number of signals that it transmits.

In mammals, three types of SK channel – SK1, SK2 and SK3 – are found throughout the brain. Studies in rats have shown that SK2 and SK3 are embedded in the cell membrane and act as channel proteins. However, SK1 does not end up in the cell membrane and does not seem to affect the electrical behaviour of brain cells.

To understand the role of SK1, Brain Function CoE researchers at the University of Queensland, led by chief investigator Pankaj Sah, looked more closely at brain cells in rats. In particular, they investigated how SK1 affected the activity of other SK channels.

The team found that after SK1 is made, it stays in a compartment inside the cell, rather than moving to the cell membrane. When SK2 is in the same compartment, the two proteins bind together, which prevents SK2 from moving to the cell membrane as well.

Rather than acting as a channel itself, SK1 seems to control the amount of SK2 in the cell membrane. In this way, SK1 can indirectly change the electrical activity of rat brain cells and, possibly, the transmission of information across the brain.

### Next steps

**The researchers are investigating whether SK1 can affect the activity of SK2 in inflammation and disease. They are also interested in testing if any mutations within SK1 are linked to specific diseases in humans.**

### Reference

Autuori, E., Sedlak, P., Xu, L., Ridder, M. C., Tedoldi, A., & Sah, P. (2019). RSK1 in rat neurons: A controller of membrane rSK2? *Frontiers in Neural Circuits*, 13, 21. doi: 10.3389/fncir.2019.00021

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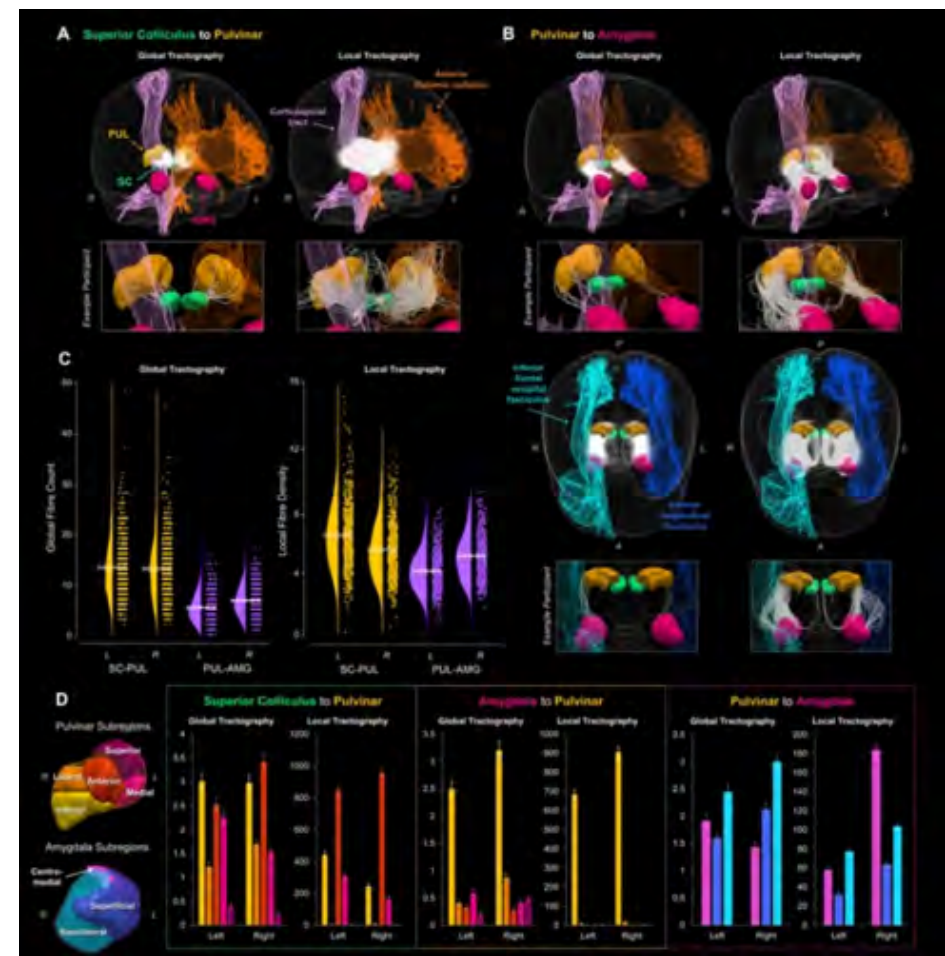
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## Salient information processing in subcortical and cortical brain pathways

Investigators: Marta Garrido, Jason Mattingley, Pankaj Sah, Nao Tsuchiya, Ilvana Dzafic, Melissa Larsen, Kelly Garner, Lena Oestreich, Jessica McFadyen, Roshini Randeniya, Claire Harris

The goal of this study is to investigate the role of a putative subcortical pathway that links thalamus and amygdala directly, the so-called “low-road”, in rapid information processing of salient, attention-grabbing stimuli, as opposed to a slow cortical route, the “high-road”, which conveys detailed information about stimuli features onto to higher order regions of the brain.

We have tested this hypothesis in a series of experiments using human neuroimaging data and modelling approaches. Interestingly, results have shown that an afferent subcortical white matter pathway to the amygdala facilitates fear recognition in humans, and individuals with greater fibre density in the pulvinar amygdala pathway are shown to have stronger dynamic coupling and enhanced fear recognition.



**Next steps**  
A comparable experiment is currently being done in rats in order to validate our findings in an animal model by using silicon probes and optogenetics we will be able to further investigate the circuitry underlying these rapid processes.

**Featured publication**  
McFadyen, J. (2019). Investigating the subcortical route to the amygdala across species and in disordered fear responses. *J Exp Neurosci*, 13, doi: 10.1177/1190695.

## IN A NUTSHELL: A newly discovered pathway in the brain helps us recognise fearful facial expressions

Researchers have found a brain pathway that quickly transmits visual information, helping to settle a debate about its existence in humans.

To evade danger, we need to detect and respond to threats quickly. These actions involve several different areas of the brain, including the amygdala – a small, highly connected structure that is responsible for coordinating fear and emotional responses.

When rodents hear sounds of danger, auditory signals are transmitted along a brain pathway to the amygdala – even if the brain region normally responsible for processing sound has been damaged. Whether a similar pathway exists for humans, and for visual information, is a topic of longstanding debate.

The location of the amygdala, deep within the brain, makes it difficult to study. But such a pathway could explain the phenomenon of ‘blindsight’ – the ability of some blind people to react to sudden movements or facial expressions without being able to see them. Although people with blindsight have vision loss as a result of damage to the primary visual cortex (V1), certain visual information seems to reach their brain through an independent pathway.

Queensland Brain Institute researcher Jessica McFadyen and her colleagues, Brain Function CoE chief investigators Jason Mattingley and Marta Garrido, looked for evidence of this pathway in humans. Using 3D modelling based on detailed brain scans from more than 600 people with undamaged V1 regions, they mapped connections between cells across the brain. In every single case, the researchers were able to reconstruct a pathway from the brainstem (which controls the flow of information between the body and the brain) to the amygdala.

Having found the pathway in humans, the researchers wanted to determine if it was involved in behaviour. They examined behavioural data from experiments in which participants were shown images of human faces and tested on their ability to recognise different expressions – fear, anger, happiness, sadness or neutral. The participants’ brain activity was measured as they completed the task, and the researchers used these measurements to make computer models of the blood flow in their brains.

The researchers found that when the participants looked at images of fearful or angry faces, the blood flow along the pathway increased. The stronger the connections were along the pathway, the better the participants were at recognising fear – but not other negative emotions, such as sadness or anger.

The discovery of the alternate pathway in humans settles a longstanding debate. In addition to explaining blindsight, it could also have implications for conditions such as autism and anxiety, which often affect how people recognise fear.

**Next steps**  
The researchers are studying whether this pathway is involved in sending rapid signals in the brain when we encounter an unexpected threat. They are also using the same experimental approach to study a person with blindsight, to see how the pathway to the amygdala has changed over time.

**Reference**  
McFadyen, J., Mattingley, J. B., & Garrido, M. I. (2019). An afferent white matter pathway from the pulvinar to the amygdala facilitates fear recognition. *eLife*, 8, e40766. doi: 10.7554/eLife.40766

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# RESEARCH REPORT

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## Cellular and circuit mechanisms underlying sensory processing in cortex

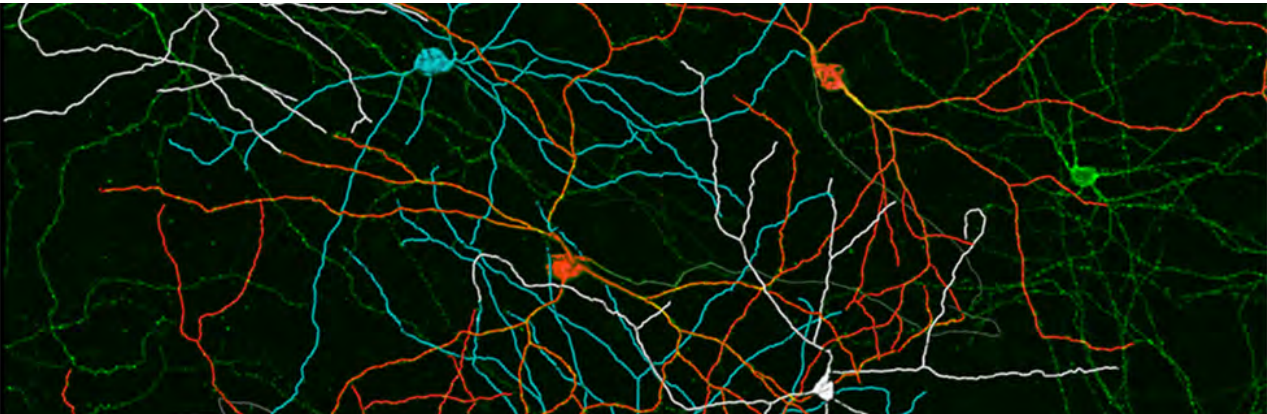
Investigators: Ehsan Arabzadeh, Greg Stuart, Jason Mattingley, Marcello Rosa, Nic Price, Mathew Diamond, Vincent Daria, Guilherme Silva, Saba Gharaei, Ehsan Kheradpezhough, Bill Connelly, Robin Broersen, Matthew Tang, Guthrie Dyce, Suraj Honnuraiah, Taylor Singh, Yadollah Ranjbar, Conrad Lee, Ben Mitchell, Mohammad Sabri, Shuan Jiang, Lachlan Owensby

Over the last decade, new methods have emerged for the characterisation of neuronal activity at the level of single cells and neuronal populations. Our strategy is to use these new methods to relate a quantitative characterisation of animal behaviour to the underlying cellular and molecular mechanisms at work in the brain.

Sensory processing provides a good setting for such investigation. This project combines two-photon calcium imaging of single cells and neuronal populations in vivo and in vitro with whole-cell and juxta-cellular recording to link neuronal activity with sensory processing in two sensory modalities - whisker touch and vision. Both sensory systems comprise well-studied pathways and have elegant structural organisation. Visual cortex contains a modular representation of the environment with a topographic map of the visual field and in rodents the whisker area of somatosensory cortex is arranged in a map of cell aggregates (barrels) with a one-to-one correspondence with whiskers. This means that sensory signals are channelled through a restricted population of neurons and can be efficiently sampled via recording electrodes or imaging, and can be targeted for modulation using optogenetics.

In this project we investigate sensory processing in the cortex at multiple levels: at the cellular level we are exploring synaptic and single cell properties involved in the integration of sensory input; whilst at the circuit and population level we are investigating how sensory processing is influenced during decision making, prediction and attention. Finally, modelling and computational analysis is used to provide a framework for interpretation of data recorded at the cellular and network level.

As a specific example, we have investigated the role of superior colliculus in attention. Our recent work demonstrates that superior colliculus modulates sensory processing in somatosensory cortex via a powerful di-synaptic pathway through the thalamus.



### Next steps

Our research has revealed the specific pathways that bring signals from superior colliculus to sensory cortex, as well as the impact of these signals on sensory coding during whisker stimulation. The next step is to investigate the impact of the superior colliculus on perceptual processing as mice engage in a sensory decision task.

### Featured Publication

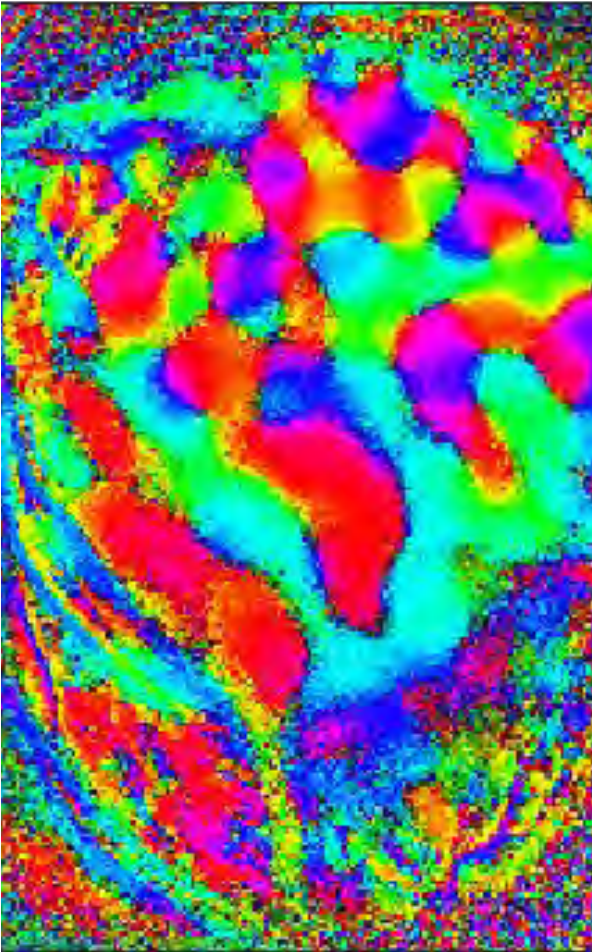
Gharaei S., Honnuraiah, S., Arabzadeh, E. and Stuart, G.J (2019) Superior colliculus modulates cortical coding of somatosensory information, *Nature Communications*, (in press)

## The role of predictive coding in receptive field formation in visual cortex

Investigators: Michael Ibbotson, Tony Burkitt, Hamish Meffin, Shaun Cloherty, Molis Yunzab, Ali Almasi, Shi Sun, Jung Jun, Artemio Soto-Breceda

Predictive Coding is a theory of brain function that has been hypothesised to explain a wide range of observations including the hierarchical organisation of (sensory) cortex, the architecture of cortical microcircuits, the structure of cortical receptive fields, single cell integration properties and synaptic plasticity. This study proposes to directly test Predictive Coding theory by combining multi-electrode array recordings from several consecutive areas in the visual pathway, with a novel information-theoretic analysis of the space-time dynamics of neural populations. Specifically, our analysis will trace the flow of information through the visual pathway in space and time, allowing us to evaluate Predictive Coding theory's predictions of where and when information should flow.

In order to effectively test this theory, we firstly developed and implemented multi-channel recording and analysis techniques to estimate models to large ensembles of stimuli. Several types of stimuli were developed in order to assess receptive fields in an objective manner, including white Gaussian noise, natural scenes and a multi-frequency contrast reversing grating stimuli. Using these stimuli as the input, we have used multiple analysis techniques (spike-triggered average, spike triggered covariance, the generalised quadratic model and the non-linear input model), to assess the receptive fields of neurons. We have comprehensively assessed the receptive fields of cells in two regions of cat cortex (areas 17 and 18), and have been able to establish a new and rigorous classification system for those cells.



### Next steps

We will study the progression of information between layers in the primary visual cortex, whilst blocking cortical activity in Area 17 and 18 while continuing to record from other areas, effectively manipulating feedback circuits.

### Featured publication

Eskikand, P.Z., Kamenev T., Burkittm A.N., Grayden, D.L., Ibbotson, M.R. (2019). Pattern motion processing by MT neurons. *Frontiers in Neural Circuits*, 13, 10.3389/fncir.2019.00043.



# RESEARCH REPORT

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## Brain systems

Coordination of activity across brain areas in real time by conducting parallel investigations in humans and animal models.



### The role of cognitive reserve and cognitive compensation in attention, prediction and decision.

Investigators: Gary Egan, Sharna Jamadar, Phillip Ward, Winnie Orchard

This project aims to bring about a paradigm shift in biomedical imaging by developing quantitative metabolic imaging using simultaneous magnetic resonance imaging (MRI) and positron emission tomography (PET). Simultaneous acquisition of MRI and PET data will enable quantitative anatomical, physiological and metabolic imaging. New MRI methods are in development for quantitative joint estimation of functional and metabolic brain activity maps. These advances will enable highly innovative new imaging approaches for advanced biomedical imaging research.

The primary goals of this study are firstly to establish and validate multimodal MR-PET research imaging methods for simultaneous quantitative functional and metabolic imaging of the human brain; and secondly, utilise these measures to investigate and understand brain circuits implicated in cognitive reserve and compensation in attention, prediction and decision-making processes.

To date, a new experimental paradigm has been developed, alongside a new radiotracer administration protocol that examines task-based functional PET simultaneously with BOLD-fMRI which have significantly improved FDG-PET resolution (from ~30mins to 16sec). These updated methods are currently being applied to explore cognitive reserve during a higher-order attention task (antisaccade task) in older versus younger adults. Work has also focused on developing dynamic kinetic models for infusion.

#### Next steps

To continue developing and validating these protocols in order to characterise the dynamics of brain function and metabolism of cognition in healthy ageing.

#### Featured publication

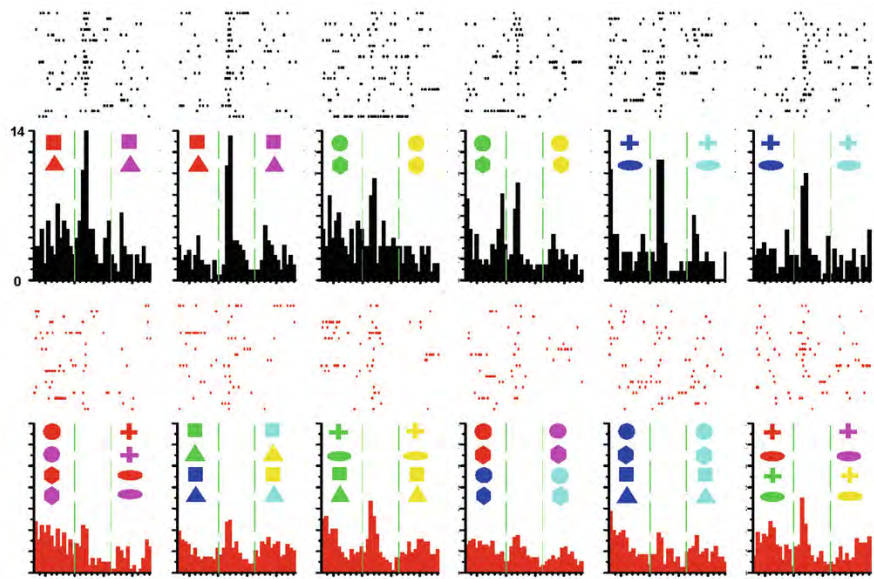
Jamadar, S.D., Ward, P.G.D., Carey, A., et al. (2019). Radiotracer Administration for High Temporal Resolution Positron Emission Tomography of the Human Brain: Application to FDG-fPET. *Journal of Visualized Experiments*, 152, 22 Oct.

# RESEARCH REPORT

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## Neural signatures of decision making in the primate cortex

Investigators: Marcello Rosa, Farshad Mansouri, Keiji Tanaka, Partha Mitra, Shaun Cloherty, Leo Lui, Daniel Fehring, Iris Zhu



This project investigates the electrophysiological activity of groups of neurones in the prefrontal, parietal and insular cortices of non-human primates trained to perform complex tasks that involve paying attention to changes in the environment, and adjusting behavioural choices accordingly.

This project uses multielectrode techniques to monitor how the information encoded by trains of action potentials relate to the animal's behaviours, and how

this information can change when certain parts of the relevant neural circuit are inactivated by lesions or reversible methods (cooling, optogenetics).

Isolating the relevant aspects of neural activity in such changing conditions has required the development of new computational analysis techniques. We have also addressed the changes in the neural circuits that underlie the performance of the cognitive tasks, by conducting diffusion tensor imaging and functional connectivity studies prior to, and after extensive training.

Thus far our studies have led to key findings which enhance our understanding of the role the prefrontal and medial frontal cortical regions in monkeys have on goal-directed processing in the executive control of behaviour.

### Next steps

To further examine whether differences exist between humans and other anthropoid apes (such as chimpanzees), to provide further insight on the functional milestones in the development of the anthropoid brain.

### Featured publication

Mansouri, F.A., Buckley, M.J., Fehring, D.J., Tanaka, K. (2020). The Role of Primate Prefrontal Cortex in Bias and Shift Between Visual Dimensions. *Cerebral Cortex*, 30, 85-99, 10.1093/cercor/bhz072

### IN A NUTSHELL:

## Making the effects of brain stimulation more predictable

**Researchers have discovered that transcranial direct current stimulation interacts with learning to affect behaviour.**

Stimulating the brain by applying a weak electrical current – using non-invasive methods such as transcranial direct current stimulation (tDCS) – can affect behaviours such as motor learning, decision-making, and multi-tasking ability. However, the effects of tDCS can vary significantly, both within and between individuals, which limits its application.

Understanding what causes this variability could enable tDCS to be used more broadly – for example, to manage the cognitive deficits that accompany many psychological disorders.

Studies have shown that tDCS can affect learning. When we learn, our brains adapt in response. They do this by changing the structure of brain cells or the connections between them. Brain Function CoE investigators wondered if the opposite might also be true – could learning affect tDCS? Differences in the level of learning in a particular task – and the extent of the resulting brain changes – might explain the variations in tDCS's effects.

To find out, investigators Daniel Fehring and Farshad Mansouri from Monash University and their colleagues tested participants on a particular task before and after applying tDCS. The tests were repeated a week apart.

Over the course of testing, the participants' performance on the task confirmed that they were learning from one week to the next. The researchers found that learning was much greater when tDCS was applied in the first week than when it was applied in the second week – indicating that the effects of brain stimulation depend on the level of learning in the task.

The researchers' findings could help to adjust the dosage and frequency of tDCS depending on the level of learning in a particular task. This could reduce the variability in the effects of tDCS, making brain stimulation more predictable and beneficial for the treatment of psychological conditions.

### Next steps

**The researchers plan to further study how changing the way tDCS is applied – for example, by varying its type, intensity or duration – might influence its effects on behaviour. They will also investigate whether other factors, such as the type of learning or an individual's sex, have an effect.**

### Reference

Fehring, D. J., Illipparampil, R., Acevedo, N., Jaberzadeh, S., Fitzgerald, P. B., & Mansouri, F. A. (2019). Interaction of task-related learning and transcranial direct current stimulation of the prefrontal cortex in modulating executive functions. *Neuropsychologia*, 131, 148–159. doi: 10.1016/j.neuropsychologia.2019.05.011



# RESEARCH REPORT

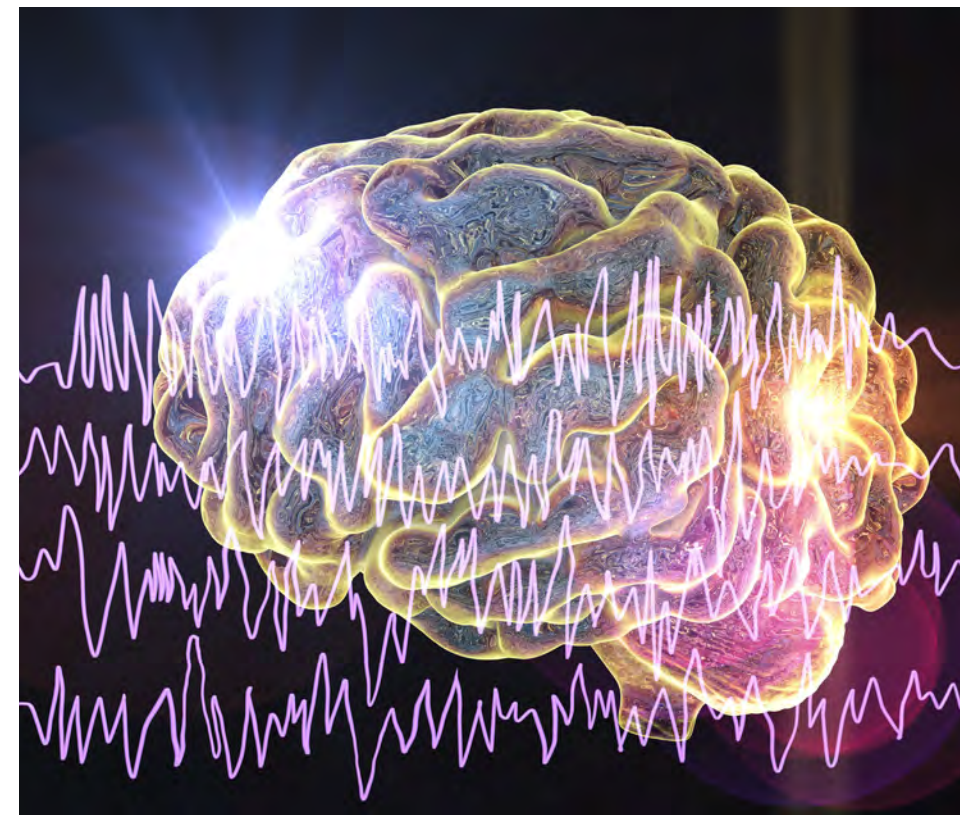
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## Understanding human attention, prediction and decision-making using psychophysics, brain imaging and neural stimulation

*Investigators: Jason Mattingley, Marta Garrido, Gary Egan, Ehsan Arabzadeh, Michael Ibbotson, Paul Dux, Matthew Tang, Chris Nolan, Oliver Baumann, Claire Bradley, Hannah Filmer, Delphine Levy-Bencheton, David Painter, Dragan Rangelov, Luke Hearne, Anthony Harris, Morgan McIntyre, Nicholas Bland, Angela Renton, Cooper Smout, Susan Travis, Imogen Stead, Emily McCann*

This project combines novel behavioural experiments with functional brain imaging (fMRI and EEG) and neural stimulation (TMS and transcranial direct-current stimulation (tDCS)) to determine the neural circuits responsible for attention, prediction and decision-making in healthy human participants. Our focus is to characterise how stimulus information from the external environment (visual, auditory, somatosensory) is filtered on the basis of high-level cognitive sets in the service of flexible and adaptive goal-directed behaviour.

Across a series of experiments we have studied how regions of the prefrontal and parietal cortices coordinate bottom-up and top-down signals during simple selective attention tasks (e.g., spatial cueing, visual search), decision-making tasks (e.g., probability judgments) and prediction tasks (e.g., oddball detection, statistical learning). We have applied Bayesian approaches to modelling the functions of these networks, and will endeavor to understand the underlying neural mechanisms at the level of individual neurons through single-cell recordings carried out in rodents and non-human primates.



### Next steps

To combine imaging methodologies with invasive recordings across multiple brain sites in animal models, to better understand the neuronal mechanisms underlying attention, prediction and decision-making.

### Featured publication

Tang, M.F., Ford, L., Arabzadeh, E., Enns, J.T. Visser, T.A.W., & Mattingley, J.B. (2019). Neural dynamics of the attentional blink revealed by encoding orientation selectivity during rapid serial visual presentation. *Nature Communications*, 11(1), e434.

### IN A NUTSHELL:

## Paying attention promotes surprise-based brain activity

**Populations of brain cells involved in managing surprise become more active with attention to visual stimuli.**

The human brain processes a massive amount of sensory information each day, enabling us to interpret everything we see, smell, hear, taste and touch – and respond appropriately. To manage this workload in the most efficient way, the brain builds a predictive model of the outside world and updates it when surprising events occur. At the same time, attention helps the brain to process the most important sensory events first.

Although we use attention and prediction all the time, researchers didn't know exactly how they work together in the brain. To find out, Brain Function CoE investigators Cooper Smout, Matthew Tang, Marta Garrido and Jason Mattingley investigated what type of information is processed in the human brain when we pay attention to expected or surprising visual events in the environment.

The researchers asked participants to view a monitor showing patterns in orientations that were either predictable, surprising or unpredictable. In some cases, the participants were asked to look out for particular changes in the appearance of the patterns, and to press a button as soon as they detected a change. In other cases, they were asked to focus instead on a dot on the monitor, thus ignoring the patterns in the background. While participants completed the tasks, their brain activity was recorded using electroencephalography.

The researchers found that paying attention to patterns increased the activity of populations of brain cells that manage surprise. The brain pathway for managing surprise assesses the difference between observed and predicted events, helping the brain to refine its predictions so it can respond more efficiently when it next encounters the same event.

The fact that these populations of brain cells are most active in response to surprising, 'attended' events suggests that attention and prediction both operate within the same fundamental pathway in the brain.

### Next steps

**The researchers are following this line of research to see how and whether the same mechanisms are involved in other types of attention, such as paying attention to a particular colour in a visual scene.**

### Reference

Smout, C.A., Tang, M.F., Garrido, M.I., & Mattingley, J.B. (2019). Attention promotes the neural encoding of prediction errors. *PLoS Biology* 17(2): e2006812

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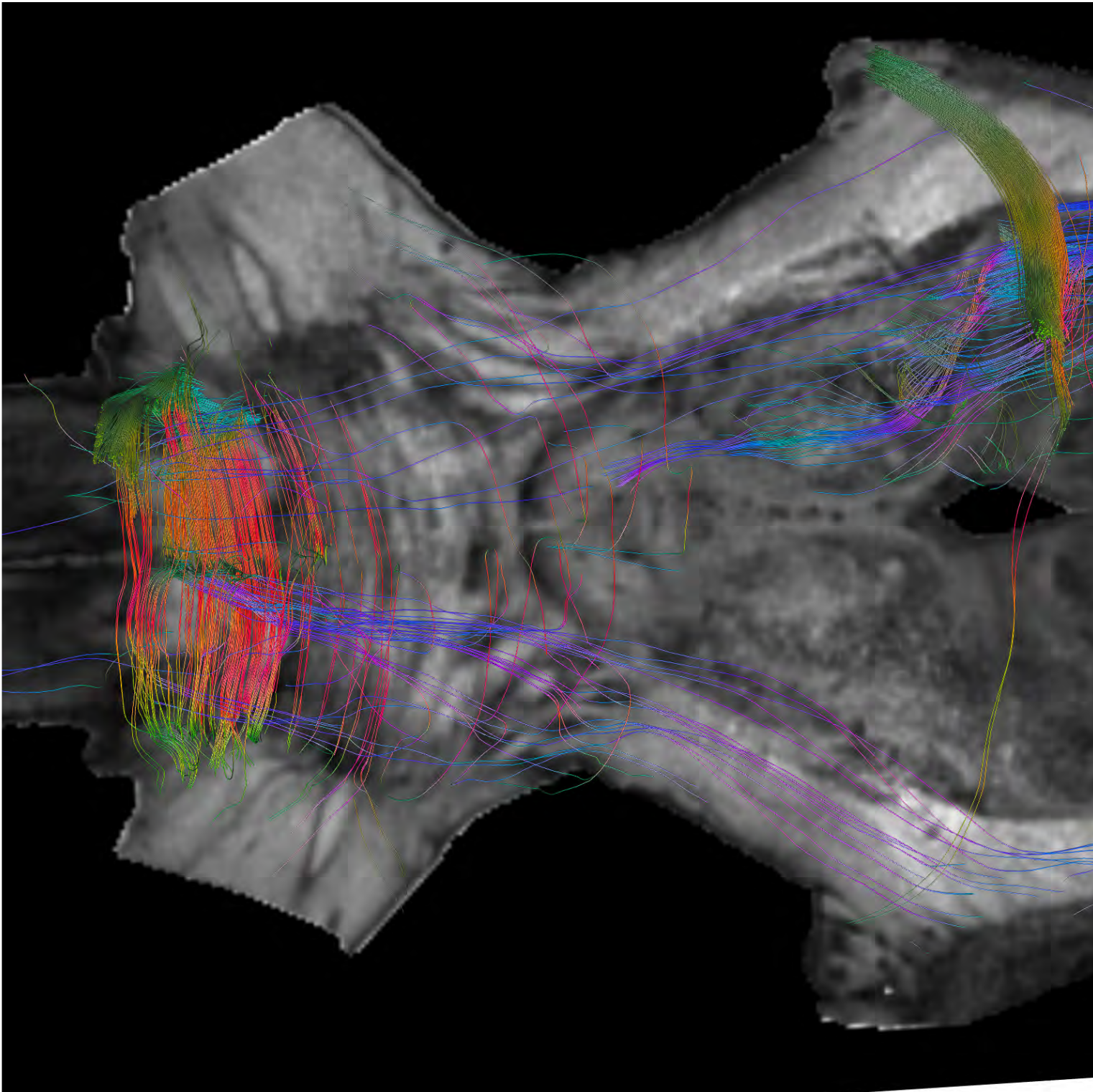


# RESEARCH REPORT

cells & synapses • networks & circuits • brain systems • **models, technologies & techniques**

## Models, technologies & techniques

Topics include technology (computational, optical, electrical and biochemical), behavioural, neuroimaging and electrophysiological techniques, models (Bayesian inference, predictive coding and error correction).



## A high-resolution 3D-MRI atlas of the human brain

Investigators: George Paxinos, G. Allen Johnson, Charles Watson, Teri Furlong, Steve Kassem, Christodoulous Skilros

The Paxinos lab is constructing a new generation of brain and spinal cord maps to assist scientists in navigating seamlessly between the central nervous system of humans and experimental animals. We will construct digital high-resolution 3D-MRI atlases for the living and post-mortem human brain. These atlases will combine multiple image modalities, eg, T1w, T2\* from in vivo at 3T and 7T, and will be an excellent companion to our histology atlas that we published last year. Furthermore, aligning these images into a common 3D space will allow navigation between the various data types, and the resulting atlases will be directly relevant to scientists and clinicians that study normal and disease states. The open-access, high-resolution templates and segmentations will allow clinical and scientific data to be aligned into our reference frame, providing a convenient, powerful reference tool for researchers and clinicians.

To date we have completed the delineations of brain regions of MRI post-mortem brainstem, identifying the boundaries of at least 300 different structures across approximately 60 levels of brainstem in the coronal plane. This level of delineation is significant as it is almost as many structures that were identified in our previous histological atlas, and offers by far the greatest delineations than any another brain atlas or tool. Further, the same structures have now also been identified in the sagittal plane at 30 different levels. The resolution, delineation and view of the sagittal planes are novel and have never before been created despite this plane of view being the one that most clinicians use. Thus, these images in the sagittal plane are a necessity to improve how scientists and clinicians utilise images of the brain.

In addition, we are using post-mortem brainstem data to make important and unique observations regarding the connections and organisation of the brainstem (using a technique called tractography), and continue to work on our histological atlas of the human brainstem (the book of which is now available). This analysis has led to the discovery of a new brain region that is unique to primates, named the endorestiform nucleus due to its location within the restiform body. This discovery (picked up by over 600 media outlets across 50 countries) is of major importance as it will now allow neuroscientists to determine its function and anatomical connections.

### Next steps

To commence work delineating brain structures from whole brain MRI scans of living human subjects.

### Featured publication

Paxinos, G., Furlong, T., Watson, C. *Human Brainstem: Cytoarchitecture, Chemoarchitecture, Myeloarchitecture*, Academic Press Elsevier, San Diego, 2019.



# RESEARCH REPORT

cells & synapses • networks & circuits • brain systems • **models, technologies & techniques**

## A cellular-scale connectome of the primate brain

Investigators: Marcello Rosa, Farshad Mansouri, Pulin Gong, Partha Mitra, Nafiseh Atapour

This project has produced the first comprehensive publicly available digital map of the connections in a primate brain. Using statistical ‘data mining’ techniques, these researchers continue to explore the network characteristics of this system, allowing new insights on how the brain works as an integrated system, which is helping to understand how information processing in the brain changes as result of diseases and normal ageing.

Whilst the initial aim of this project (data collection and development of platform for sharing) was achieved some time ago, this project continues to exceed expectation with a number of additional milestones achieved.

As we reach >150 tracer injections made publicly available, we have advanced the analysis of the statistical properties of the cortico-cortical connectome. We have also made important advances in methodology for this type of work, including new pipelines for registration and visualisation of neuroanatomical data, which result in significantly more accurate assignment of connections to specific areas of the brain. These advances have been incorporated in papers which have been published.

With international collaborators, we have started using the new methods to address the question of neuronal diversity, a key property of the cortical circuit. In addition, we are seeing increasing uptake of the resource by other groups. This has led, for example, to two papers published recently in Nature Communications (Buckner and Magulies, and Liu et al., both 2019)



### Next steps

To continue expanding tracer injection sites and improving methodology, with the ultimate ambition of developing parallel protocols for use in rodents and humans.

### Featured publication

Lin, M.K., Takahashim Y.S., Huom B.X., Hanadam M., Nagashimam J., Hatam J., Tolpygom A.S., Ramm K., Lee, B.C., Miller, M.I., Rosa, M.G., Sasaki, E., Iriki, A., Okano, H., Mitra, P. (2019) A high-throughput neurohistological pipeline for brain-wide mesoscale connectivity mapping of the common marmoset. *Elife*, 8, e40042. doi: 10.7554/eLife.40042.

<http://www.marmosetbrain.org/>

### IN A NUTSHELL:

## Taking the first census of cells in a primate brain

Using a newly developed method, researchers have produced a more accurate record of the number and location of cells in the brain.

To understand how the structure of the brain is linked to its development and function, researchers need to know how many cells are in each part of the brain. This is important, for example, when creating simulations of brain activity. However, this basic information has been surprisingly difficult to obtain.

A current method, called isotropic fractionation, uses a soup-like mixture of pulverized brain cells to give an approximate number, but in the process it loses information about which parts of the brain contain which cells.

Now, Brain Function CoE investigators Nafiseh Atapour, Piotr Majka and Marcello Rosa, along with colleagues at Monash University, have produced the first complete map of cells in a primate cerebral cortex – the thick outer layer of folded grey matter that covers much of the surface of the brain and is involved in consciousness.

The researchers cut the cerebral cortices from a marmoset monkey vertically into columns measuring 1 square millimetre at their top surface. After staining them to reveal individual brain cells, they took digital images of the columns so they could zoom in and count the cells. A total of 116 structural areas have been defined in the marmoset cortex, so the researchers grouped the columns into these areas to investigate how cell density varies across the brain.

Based on their comprehensive census, the researchers estimate that the marmoset cerebral cortex contains approximately 300 million cells. Cell density varies significantly across the structural areas, with some areas almost four times as dense as others. For example, the primary visual cortex, which processes visual information, has more than 150,000 cells per cubic millimetre of brain – adding up to more than a quarter of the total cells in the marmoset cerebral cortex. By contrast, some allocortical areas – thinner regions of the brain that include the area responsible for processing odour – have only around 50,000 cells per cubic millimetre.

Previously, it was believed that brain areas performing more complicated cognitive tasks would have fewer cells, because more space was needed for the wiring that transmits information between cells. The researchers showed that this was true for some areas, but not others – suggesting that other factors are involved in the relationship between cell density and brain function. They believe that the way different genes are turned on and off in the cells within each cortical area during brain development may help to influence the cell density in those areas.

### Next steps:

**The researchers plan to look at different subtypes of brain cells to see if and how their number and location vary across the brain. They are also developing automated methods for identifying these subtypes, so that this type of work can be conducted more rapidly in the future.**

### Reference:

Atapour, N., Majka, P., Wolkowicz, I. H., Malamanova, D., Worthy, K. H., & Rosa, M. G. P. (2018). Neuronal distribution across the cerebral cortex of the marmoset monkey (*Callithrix jacchus*). *Cerebral Cortex*, bhy263. doi: 10.1093/cercor/bhy263

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# RESEARCH REPORT

cells & synapses • networks & circuits • brain systems • **models, technologies & techniques**

## Unified neural models for attention, prediction and decision including quantitative analysis of brain structure, function, and stimulation

Investigators: Peter Robinson, Pulin Gong, Benjamin Fulcher, Svetlana Postnova, Tahereh Babaie-Janvier, Natasha Gabay, James Henderson, Tahereh Tekieh, Dongping Yang, Massoud Aghili Yajadda



Many current models for attention, prediction and decision (APD) rely on complex assumptions, and/or commonly used phenomenological graph-theoretic and statistical approaches that overwhelmingly ignore the brain's physical structure and geometry. In contrast, this project is developing techniques that model and analyse the brain from a quantitative physical perspective that respects its main physical and biological characteristics and brings to bear analysis methods translated from the physical sciences. This has resulted in new insights and approaches, which are being made available as freely accessible software tools.

This approach has allowed us to formulate a unified model of APD with foundations in realizable neural dynamics. The current model has emergent features in common with engineering data fusion algorithms, that correspond to the known Bayes-like signal integration that occurs in multimodal sensory tasks, but are based on neural processes and states. Results from the model are also enabling new testable predictions and hypotheses to be formulated, particularly in the area of sensory processing and intracortical communication. Central to the work is

the formulation of brain activity, structure, and function in terms of physically meaningful natural modes, rather than phenomenological statistical constructs such as 'resting state networks' or graphs. Natural modes provide compact descriptions of brain structure and dynamics and allow deeper understanding in terms of physical brain properties.

A number of software tools have been made available via methods publications and dissemination through appropriate websites. These include brain-state tracking software based on dynamic real-time EEG fitting to neural field predictions, research-ready neural field simulation software, and functional MRI analysis software that permits multiple underlying physical quantities to be imaged noninvasively using model-based analysis.

Full access to these tools (providing appropriate acknowledgement is given in any resulting publications) can be found at <https://github.com/BrainDynamicsUSYD>

### Next steps

Cognitive changes that underly in evoked responses to different stimuli are being modeled to explain attention, mismatch negativity, and related phenomena from first principles. Collaborations on data analysis and interpretation are being pursued. On a fundamental level, analysis of brain properties in terms of eigenmodes is progressing with the aim of replacing ad hoc phenomenological methods by systematic, physically based ones.

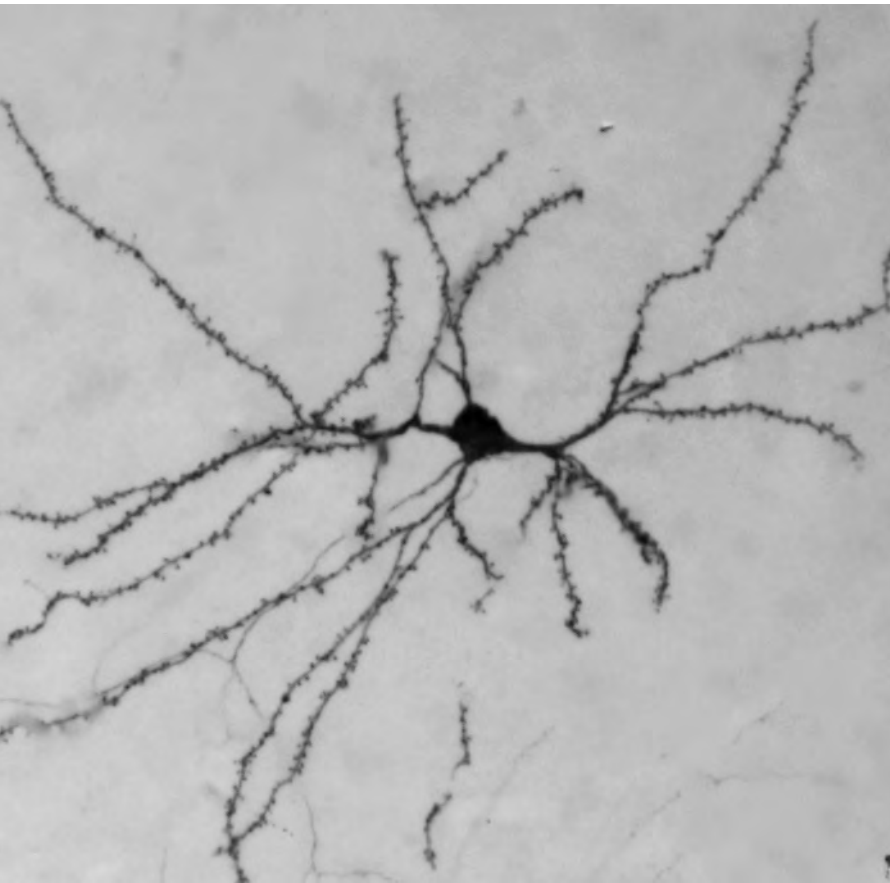
## Real time analysis of network function using an all optical interface

Investigators: Steve Petrou, Tim Karle

This project seeks to develop an all optical interface to study single cell and network function of cultured neurons. Next generation voltage sensitive proteins called QUASARS enable high temporal resolution imaging of transmembrane action potentials. Spectrally compatible optogenetic activation is also possible to enable simultaneous activation and recording on neuronal function. The goal is to develop an imaging system that enables fast (1kHz) imaging with high resolution (1M pixel) optogenetic stimulation on a custom-built microscope with high magnification (20X and 60X high NA) for single neuron imaging as well as low magnification wide field (2X 0.5NA) for network level imaging.

We have developed new instrumentation that will enable whole neuron imaging of membrane potential and the exploration of how single neurons compute. A prototype for narrow field imaging has been designed, with equipment needed for complete development purchased. Control software has been written in Matlab, LabView and Python and the system is undergoing validation analysis.

Deployment of this system will allow for comprehensive analysis of dendritic processing, with an aspirational goal of exploring neuronal transfer functions and action potential initiation.



### Next steps

An infrared laser is being tested as to the feasibility of using an IR dye, for voltage imaging over very wide fields of view ( >1mm<sup>2</sup>) with 5 ms time resolution, in addition to the inclusion of an incubator stage to allow longer duration measurements.

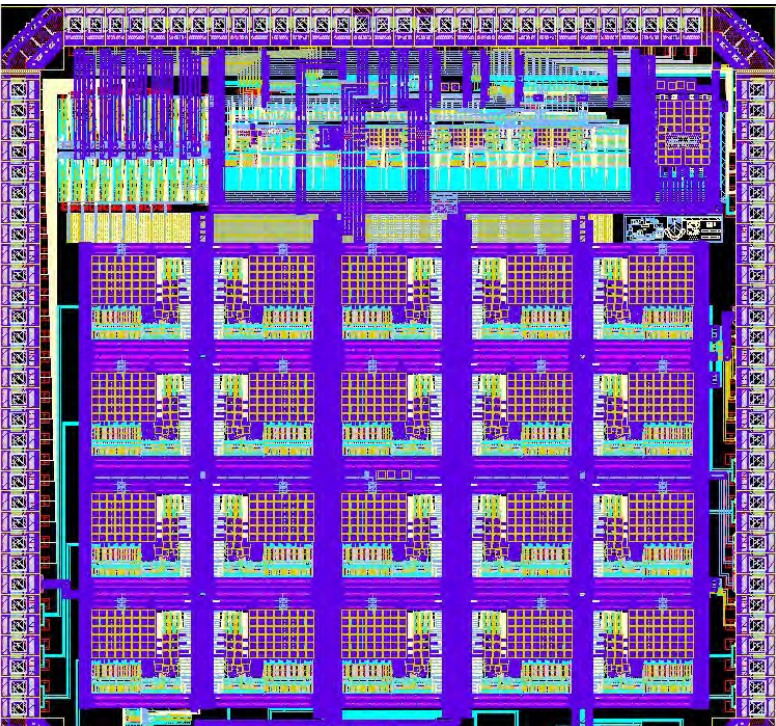


# RESEARCH REPORT

cells & synapses • networks & circuits • brain systems • **models, technologies & techniques**

## Brain machine interface tiles

Investigators: Arthur Lowery, Timothy Feleppa, Anand Mohan, Yan Wong, Tim Allison-Walker



We are developing a wireless system capable of continuously recording and interpreting neuronal activity. Electrical neural signals (spiking and local field potentials) are recorded from a microelectrode array implanted directly into the brain, via a custom-designed microchip and wireless electronics.

We have completed our 2nd generation microchip using Synopsys computer aided design tools. This involved designing a large number of sub-circuits (amplifiers, signal filters, ADC, digital processing) which have significantly improved on the previous generation chip's performance and capabilities. These improved sub-circuits will amplify and digitise neural signals with lower noise, reduced interference, and increased resolution, providing higher measurement fidelity and detecting weaker neural signals.

A new wireless inductive link is currently being

developed which will allow full-duplex communications (uplink and downlink simultaneously). This allows the implant to be safely wirelessly powered with a miniature implanted coil (<10x10mm) without the use of implanted batteries.

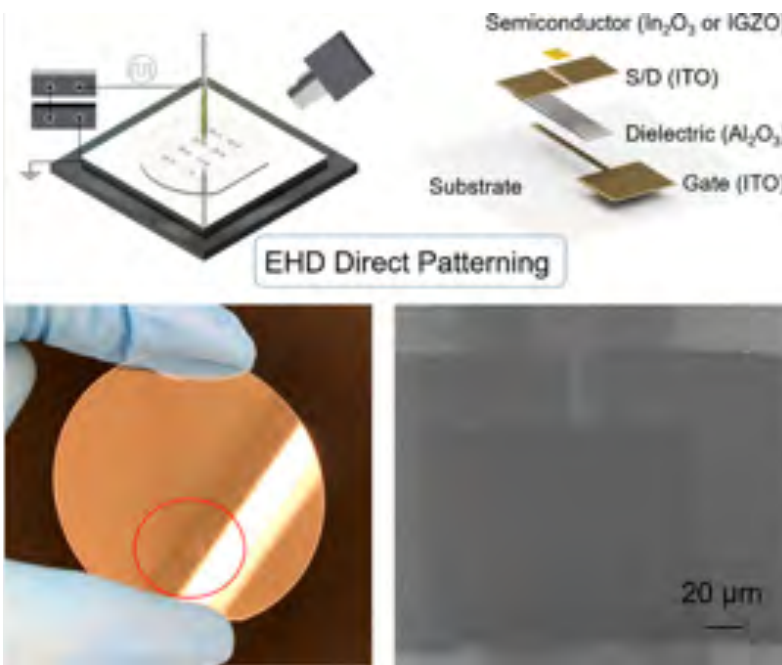
In vivo experiments have been conducted in collaboration with CI Marcello Rosa's team, where a functional prototype of the system based on a 1st generation microchip was tested, generating continuous neural recordings from rodent subjects. Data collected and feedback from collaborators have provided valuable insights for improvement of the microchip and associated hardware and software.

### Next steps

2nd generation microchip has been received with *in vivo* testing of this version commenced.

## Printable electronics for wide area neural recording

Investigators: Stan Skafidas, Babak Nasr



This project sees the development of novel printable and dissolvable electronics that will be conformable with brain structure and allow recording across a wide area of the brain. This technology will allow the recording of brain activity in awake animals, with minimal disruption to normal brain activity.

After collaboration with neuroscientists, biologists and physicists, new tools are in development that manipulate and record from both single nerve cells and collections neurons forming fundamental circuits in the brain.

To date we have demonstrated an electrohydrodynamic based printing process that reliably fabricates high-performance metal oxide thin-film transistors with feature sizes smaller than 2 µm.

Using our approach we have been able to fabricate high-performance and high-reliability transparent electronics. This work is highly innovative and is likely to lead to commercialisation outcomes and critically lead to publications in the best international journals in the field.

### Next steps

Further improvements in resolution are expected with further refinements to the printer and higher control of the environment where the printing is undertaken.

### Featured publication

Liang, Y., Yong, J., Yu ,Y., Nirmalathas, A., Ganesan, K., Evans, R., Nasr, B., Skafidas, E. (2019). Direct electrodynamic patterning of high-performance all metal oxide thin-film electronics. *ACS Nano*, 13(12), 13957-13964. 10.1021/acsnano.9b05715



2 Books

2 Book chapters

2 Conference papers

93 Journal articles

Roll over number markers for highlights

Books

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2. Paxinos, G., Furlong, T., Watson, C. (2019). Human Brainstem: Cytoarchitecture, Chemoarchitecture, Myeloarchitecture. San Diego: Academic Press.

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3. Jamadar, S.D. (2019). Brain circuitry in ageing and neurodegenerative disease, in Degenerative Disorders of the Brain, D.R. Hocking, J.L. Bradshaw, J. Fielding, Editors., Taylor and Francis: London. p. 1-31.

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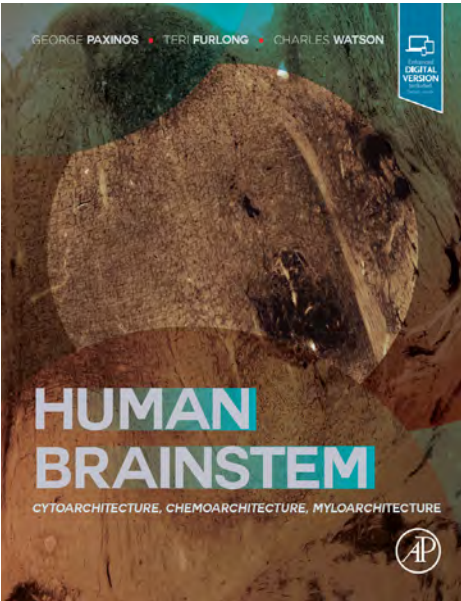
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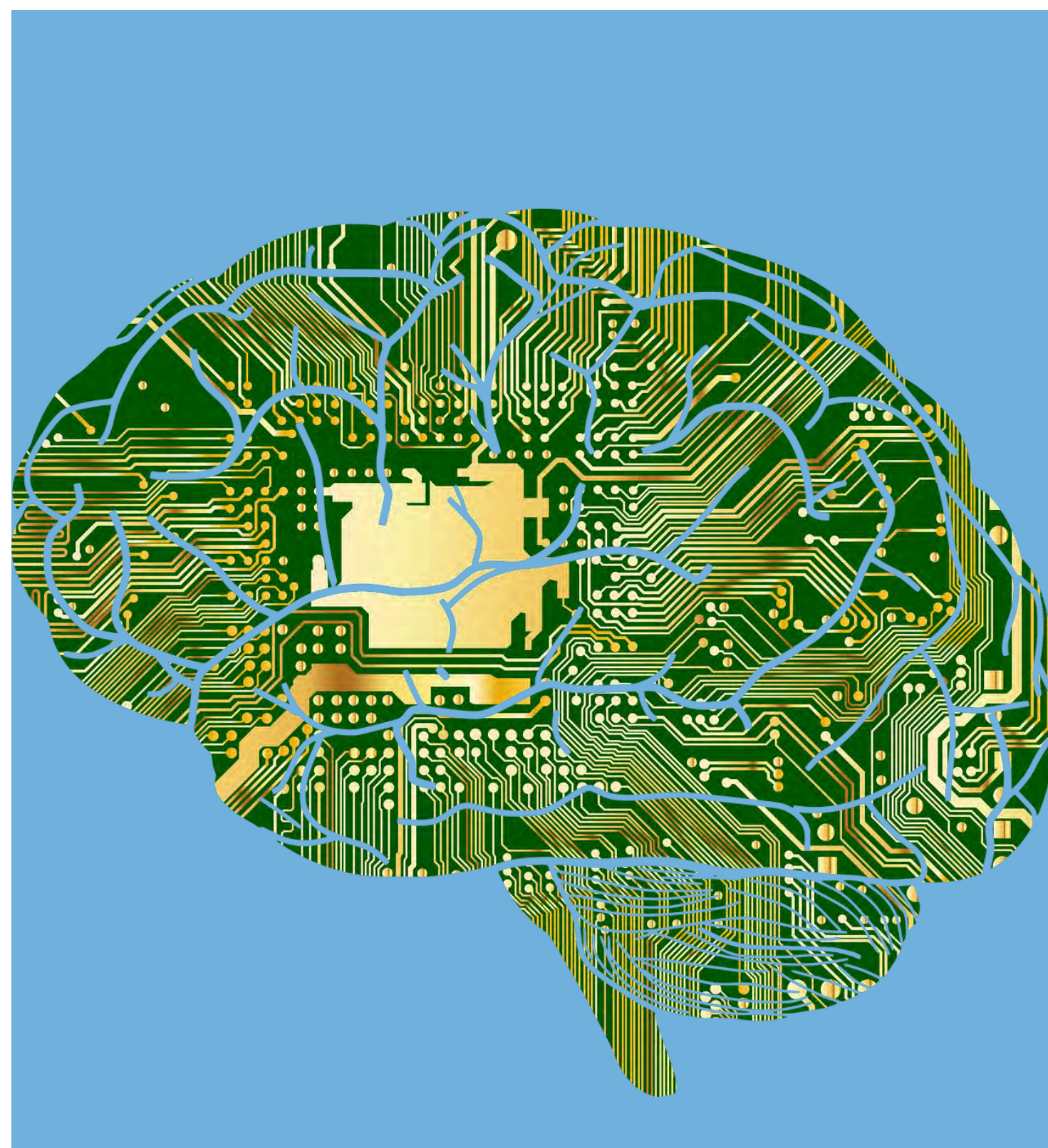
# RESEARCH REPORT

publications • presentations

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98. Zhu, S., Allitt, B., Samuel, A., et al. (2019). Distributed representation of vocalization pitch in marmoset primary auditory cortex. *Eur J Neurosci*, 49(2): p. 179-198. 10.1111/ejn.14204.
99. Zhu, S., Allitt, B., Samuel, A., et al. (2019). Sensitivity to vocalization pitch in the caudal auditory cortex of the marmoset: Comparison of core and belt areas. *Front Syst Neurosci*, 13: p. e5. 10.3389/fnsys.2019.00005.





# RESEARCH REPORT

publications • presentations

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International presentations

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National presentations

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Poster presentations

## International Presentations

- Almasi, A. Feature selectivity and invariance in primary visual cortex. *28th Annual Computational Neuroscience Meeting*. Barcelona, Spain. 13-17 July 2019.
- Bradley, C. Dynamic changes in networks for spatial attention revealed by transcranial magnetic stimulation evoked potentials. *Australasian Cognitive Neuroscience Society Conference*. Launceston, Australia. 21-24 Nov 2019.
- Dzafic, I., Larsen, M., Carter, O., et al. Regularity learning and prediction errors in the continuum of psychotic experiences *European Conference on Schizophrenia Research*. Berlin, Germany. 26-28 Sep 2019.
- Egan, G.F. The Australian Brain Alliance: Update and future plans. *10th IBRO World Congress of Neuroscience*. Daegu, South Korea. 21-25 Sept 2019.
- Egan, G.F. Global Brain Consortium meeting summary and implementation plan. *Global Brain Consortium Inaugural Meeting*. Montreal, Canada. 10 May 2019.
- Egan, G.F. Imaging neuroinflammation and neurodegeneration in vivo: new approaches using simultaneous MR-PET. *New and Emerging Technologies – Biotech meets Medicine*. Potsdam, Germany. 18-20 Sept 2019.
- Furlong, T. Habitual behaviour resulting from high-calorie food is prevented by an orexin-receptor antagonist. *39th Annual Meeting of the Australasian Neuroscience Society*. Adelaide, Australia. 2-5 Dec 2019.
- Garner, K. Cognitive capacity limits are remediated by practice-induced plasticity between the Putamen and Pre-Supplementary Motor Area. *Australasian Cognitive Neuroscience Society Conference*. Launceston, Australia. 21-24 Nov 2019.
- Gharaei, S. Superior colliculus modulates cortical coding of somatosensory information. *39th Annual Meeting of the Australasian Neuroscience Society*. Adelaide, Australia. 2-5 Dec 2019.
- Harding, I.H., et al. Brain atrophy in Friedreich ataxia preferentially manifests in cerebellar and cerebral motor areas: Results from the ENIGMA-Ataxia consortium. *International Ataxia Research Conference* Washington, USA. 14-16 Nov 2019.
- Lee, C. State dependent changes in perception and sensory coding in the somatosensory cortex. *39th Annual Meeting of the Australasian Neuroscience Society*. Adelaide, Australia. 2-5 Dec 2019.
- Mansouri, F., Rosa, M.G.P., Tanaka, K., et al. The neural architecture of cognitive flexibility and control. *Australasian Cognitive Neuroscience Society Conference*. Launceston, Australia. 21-24 Nov 2019.
- Marek, R. Neural function and connectivity to drive emotional learning. *39th Annual Meeting of the Australasian Neuroscience Society*. Adelaide, Australia. 2-5 Dec 2019.
- Martin, P.R. Form and function in parallel pathways for colour vision. *25th Symposium of the International Colour Vision Society*. Riga, Latvia. 5-9 July 2019.
- Mattingley, J. The role of prediction in sensory encoding. *39th Annual Meeting of the Australasian Neuroscience Society*. Adelaide, Australia. 2-5 Dec 2019.
- Mattingley, J. Attention modifies the weights of competing stimulus sources during integrated visual decision making. Zangwill Club invited seminar in the department of *Experimental Psychology*, University of Cambridge. Cambridge, UK. 5 Apr 2019.
- Mattingley, J. Attention modifies the weights of competing stimulus sources during integrated visual decision making. *Invited seminar in the Department of Experimental Psychology*, University of Oxford. Oxford, UK. 3 Apr 2019.
- Mattingley, J. Understanding the neural processes involved in integrated perceptual decisions. *Center for Biomedical Imaging (CBI)*, Medical University of South Carolina. Charleston, USA. 19 Jun 2019.
- Nordstrom, K., Williams, S., Martin, P.R., et al. Vision, information processing and cognition. *39th Annual Meeting of the Australasian Neuroscience Society*. Adelaide, Australia. 2-5 Dec 2019.
- Paxinos, G. Brain and Mind: Who is the Puppet and Who the Puppeteer? *Hellenic Neuroscychology Society*. Athens, Greece. 19 May 2019.
- Paxinos, G. Brain and Mind: Who is the Puppet and Who the Puppeteer? *Institute of Public Health of the American College*, Athens. Athens, Greece. 31 Oct 2019.
- Paxinos, G. Brain and Mind: Who is the Puppet and Who the Puppeteer? *Metropolitan College*. Athens, Greece. 30 Oct 2019.
- Paxinos, G. Brain and Mind: Who is the Puppet and Who the Puppeteer? *FENS Regional Meeting* Belgrade, Serbia 10-13 Jul 2019.
- Paxinos, G. Brain and Mind: Who is the Puppet and Who the Puppeteer? *Open University of Crete*. Crete, Greece 24 June 2019.
- Paxinos, G. *Opening address*. Hellenic Psychology Society. Athens, Greece. 16 May 2019.
- Paxinos, G. Brain and Mind: Who is the Puppet and Who the Puppeteer? *GeneDis Meeting*. Crete, Greece 8-11 Oct 2019.
- Paxinos, G. Brain and Mind. *Vascular Dementia Conference* Paris, France. 22 Feb 2019.
- Paxinos, G. Brain and Mind: Who is the Puppet and Who the Puppeteer? *Hellenic Pharmaceutical Student's Congress*. Patras, Greece. 25 Apr 2019.
- Randeniya, R. Bayesian models of atypical sensory perception in Autism. *39th Annual Meeting of the Australasian Neuroscience Society*. Adelaide, Australia. 2-5 Dec 2019.
- Rangelov, D. Neurocognitive consequences of prediction violation across auditory and visual modalities. *Australasian Cognitive Neuroscience Society Conference*. Launceston, Australia. 21-24 Nov 2019.
- Robinson, P.A. Physical brain connectomics and dynamics - Part 1. *LACONEU Conference*. Valparaíso, Chile. 7-11 Jan 2019.
- Robinson, P.A. Physical brain connectomics and dynamics - Part 2. *LACONEU Conference*. Valparaíso, Chile. 7-11 Jan 2019.
- Robinson, P.A. Nonlinear brain dynamics via neural field theory. *American Physical Society March Meeting*. Boston, USA. 4-8 Mar 2019.
- Robinson, P.A. Quantitative modeling and analysis of multiscale brain structure and dynamics. *4th International Conference on Basic and Clinical Multimodal Imaging*. Chengdu, China. 10-14 Sep 2019.
- Robinson, P.A. Relating brain measurements to structure and activity via modeling. *4th International Conference on Basic and Clinical Multimodal Imaging*. Chengdu, China. 10-14 Sep 2019.
- Robinson, P.A. Multiscale brain modeling. *2nd IBRO-APRC Bangladesh Associate School of Neuroscience*. Dhaka, Bangladesh. 4-8 Dec 2019.
- Robinson, P.A. Structure-function relationships via eigenmodes. *BrainModes*. Pokhara, Nepal. 12-13 Dec 2019.
- Rosa, M.G.P. Marmoset brain connectivity atlas. *Building and Mining Brain Cell Atlases and Connectomes*. Suzhou, China. 3-19 June 2019.



# RESEARCH REPORT

publications • presentations

39. Rowe, E., Tsuchiya, N., Garrido, M. Detecting (un) conscious prediction errors. *Australasian Cognitive Neuroscience Society Conference*. Launceston, Australia. 21-24 Nov 2019.

40. Sah, P. Computational features of the amygdala. *Amygdala Function in Emotion, Cognition and Disease. Gordon Research Conference*. Easton, USA. 4-9 Aug 2019.

41. Sah, P. Prefrontal cortex, hippocampus and amygdala: a tripartite circuit for fear learning. *9th Federation of the Asian and Oceanian Physiological Societies (FAOPS) Congress; Symposium on Amygdala Neuronal Circuits in adaptive Behaviours*. Kobe, Japan. 28-31 Mar 2019.

42. Sah, P. The science of learning: From the laboratory to the classroom. *China Brain Science and Education International Summit*. Qingdao, China. 10-11 May 2019.

43. Sah, P. Deep brain stimulation in the 21st century: Movement disorders to psychiatric disorders; Tourette's pain, depression and addiction. *China-Australia Seminar of Brain Science Research and Training Course on Functional Neurosurgery & The 4th Pengcheng Minimally Invasive Neurosurgery Summit Forum*. Shenzhen, China. 10 Aug 2019.

44. Sah, P. Neural circuits that mediate fear learning and extinction; mechanisms and issues. *RIKEN Center for Brain Science seminar program*. Tokyo, Japan. 26 Mar 2019.

45. Sah, P. How can partial reinforcement be implemented in the classroom for ideal learning? *Lund Symposium on Cognition, Communication and Learning*. Lund, Sweden. 24-26 Apr 2019.

46. Stead, I. Modelling of spatial representations across eye movements reveals rapid post-saccadic updating. *Australasian Cognitive Neuroscience Society Conference*. Launceston, Australia. 2019.

47. Stuart, G. Cellular and circuit mechanism underlying binocular vision. *RTG Symposium on Cortical Sensations*. Aachen, Germany. 4 Oct 2019.

48. Stuart, G. Heterogeneity of dendritic properties from rodents to humans. *Gordon Research Conference on Dendrites*. Ventura, USA. 31 Mar - 5 Apr 2019.

49. Ward, P.G.D., Liang, E., Egan, G.F., et al. Dynamic within-subject functional connectivity in the resting state using high temporal resolution simultaneous BOLD-fMRI FDG-PET. *39th Annual Meeting of the Australasian Neuroscience Society*. Adelaide, Australia. 2-5 Dec 2019.

50. Yunzab, M., Choi, V., Meffin, H., et al. Synaptic basis for contrast-dependent shifts in functional identity in mouse V1. *28th Annual Computational Neuroscience Meeting*. Barcelona, Spain. 13-17 July 2019.

## National Presentations

51. Bryson, A. Tonic Currents and Neuronal Excitability. *Epilepsy Research Retreat*. Ballarat, Australia. 8-10 Aug 2019.

52. Chen, G., Gong, P. Dynamical circuit mechanisms of attentional sampling. NeuroEng 2019: *The 12th Australasian Workshop on Computational Neuroscience and Neural Engineering*. Adelaide, Australia. 29-30 Nov 2019.

53. Dyce, G.P. Spatial attention in the vibrissal system of mice. *Kioloa Neuroscience Colloquium*. Kioloa, Australia. 25-26 May 2019.

54. Egan, G.F. Invited presentation. *Monash Health Neuroscience Symposium*. Clayton, Australia. 28 Feb 2019.

55. Egan, G.F. Emerging needs and opportunities for accelerator based production of therapeutic medical radioisotopes. *Nuclear Science & Technology for Heath Symposium*. Clayton, Australia. 31 May 2019.

56. Furlong, T. Dopamine and habitual actions. *Dopamine Symposium*, UNSW. Sydney, Australia. 14 Nov 2019.

57. Furlong, T. Breaking bad habits: loss of behavioural control by methamphetamine and high-calorie diet. *BOSCH young Investigator symposium*. Sydney, Australia. 29 Dec 2019.

58. Garner, K., Garrido, M., Dux, P. Cognitive capacity limits are remediated by practice-induced plasticity in a striatal-cortical network. *Australian HBM Chapter meeting* Newcastle, Australia. 16-18 Oct 2019.

59. Garrido, M. From prediction errors to computational psychiatry. *Biological Psychiatry Australia*. Melbourne, Australia. 27-29 Oct 2019.

60. Garrido, M. DCM study on coma/ vegetative states & schizophrenic patients. *Brain Mechanism of Loss of Consciousness Workshop*. Melbourne, Australia. 1 Mar 2019.

61. Garrido, M. From prediction errors to computational psychiatry. *Students of Brain Research Symposium* 2019. Melbourne, Australia. 12 Nov 2019.

62. Garrido, M. Why can blind people “see” emotion? *UNSW School of Psychology Seminar*. Sydney, Australia. 8 Feb 2019.

63. Gharaei, S. Superior colliculus modulates cortical coding of somatosensory information. *Kioloa Neuroscience Colloquium*. Kioloa, Australia. 25-26 May 2019.

64. Ibbotson, M.R. Invited panel member: The interface between wet and dry neurosciences. *NeuroEng 2019: The 12th Australasian Workshop on Computational Neuroscience and Neural Engineering*. Adelaide, Australia. 29-30 Nov 2019.

65. Jung, J., Yunzab, M., Almasi, A., et al. Orientation maps in the primary visual cortex of the Australian Tammar Wallaby NeuroEng 2019: *The 12th Australasian Workshop on Computational Neuroscience and Neural Engineering*. Adelaide, Australia. 29-30 Nov 2019.

66. Kheradpezhough, E., Tang, M.F., Mattingley, J.B., et al. TRPA1 activation enhances sensory coding in mouse vibrissal and visual cortices. *The Gage Conference on Ion Channels and Transporters*. Canberra, Australia. 15-17 Apr 2019.

67. Linghan, J. SCN2A GOF vs LOF assessed in cortical culture neuronal networks. *Epilepsy Research Retreat*. Ballarat, Australia. 8-10 Aug 2019.

68. Mattingley, J. Understanding the neuroscience behind attention, prediction and decision making. *Invited seminar at Cricket Australia*. Brisbane, Australia. 10 Apr 2019.

69. Mattingley, J. Visual cortex hyper-excitability in individuals with Charles Bonnet hallucinations. Invited Talk in *Neurology Department, Mater Hospital*. Brisbane, Australia. 26 Mar 2019.

70. Mattingley, J. Human behavioural and physiological investigations of attention, prediction and decision -making in health and disease. *The Mater Research/ Queensland Brain Institute Research Symposium*. Brisbane, Australia. 12 Oct 2019.

71. Mattingley, J. How we think: Cracking the brain's code. *Medical Moonshots*. Canberra, Australia. 26 Sept 2019.

72. Mattingley, J. Understanding the neural processes involved in integrated perceptual decisions. *The Research School of Psychology, ANU*. Canberra, Australia. 27 Sept 2019.

73. Meffin, H., Almasi, A., Cloherty, S.L., et al. Nonlinear receptive field estimation reveals novel forms of feature invariance in primary visual cortex. NeuroEng 2019: *The 12th Australasian Workshop on Computational Neuroscience and Neural Engineering*. Adelaide, Australia. 29-30 Nov 2019.

74. Paxinos, G. Brain and Mind: Who is the Puppet and Who the Puppeteer? *APS College of Clinical Neuropsychologists* Adelaide, Australia 7 Nov 2019.

75. Petrou, S. Estimating neuronal conductance model parameters using dynamic action potential clamp. *Epilepsy Research Retreat*. Ballarat, Australia. 8-10 Aug 2019.

76. Rangelov, D. Behavioural and neural correlates of integrated decision making. *UQ School of Psychology Seminar Series*. Brisbane, Australia. 30 Aug 2019.

77. Tang, M.F. Prediction affects sensory coding. *QIMR Seminar Series*. Brisbane, Australia. 1 Nov 2019.

78. Tang, M.F. Prediction affects sensory coding. *QIMR UQ School of Psychology Seminar Series*. Brisbane, Australia. 29 Jul 2019..

79. Tang, M.F. Prediction affects sensory coding. *Eccles Institute of Neuroscience, Australian National University*. Canberra, Australia. 2 Aug 2019.

80. Wong, Y. Cortical vision prosthesis evoked spiking exhibits phase-dependency. NeuroEng 2019: *The 12th Australasian Workshop on Computational Neuroscience and Neural Engineering*. Adelaide, Australia. 29-30 Nov 2019.





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## Poster Presentations

81. Almasi, A., Cloherty, S.L., Wong, W.T., et al. Almasi, A., Cloherty, S.L., Wong, W.T., Ibbotson, M.R., Meffin, H. *28th Annual Computational Neuroscience Meeting*. Barcelona, Spain. 13-17 July 2019.
82. Almasi, A., Sun, S., Yunzab, M., et al. How do stimulus statistics change the receptive fields of cells in primary visual cortex? *28th Annual Computational Neuroscience Meeting*. Barcelona, Spain. 13-17 July 2019.
83. Babaie-Janvier, T., Robinson, P.A. Corticothalamic prediction and attention with control systems analysis. *2019 Organization for Human Brain Mapping Annual Meeting*. Rome, Italy. 9-13 June 2019.
84. Bhattarai, A., Chen, Z., Talman, P., et al. Longitudinal assessment of white matter diffusion changes in limb-onset Amyotrophic lateral sclerosis. *Australian HBM Chapter meeting* Newcastle, Australia. 16-18 Oct 2019.
85. Close, T.G., Sforazzini, F., Ward, P.G.D., et al. Biomedical imaging analysis in arcana (Banana): a platform for collaborative development of neuroimaging analysis workflows. *2019 Organization for Human Brain Mapping Annual Meeting*. Rome, Italy. 9-13 June 2019.
86. Cong, W. Brain oscillations - a way to understand memory and learning. *Brisbane Life Sciences Symposium*. Brisbane, Australia. 7 Jun 2019.
87. Cong, W. Neural activity in the medial prefrontal cortex and hippocampus that encodes novel object recognition. *Neuroscience 2019*. Chicago, USA. 19-23 Oct 2019.
88. Deebea, F., Sanz-Leon, P., Robinson, P.A. Unified dynamics of interictal events and absence seizures. *International Conference for Technology and Analysis of Seizures*. Exeter, UK. 2-5 Sep 2019.
89. Dyce, G.P., Tang, M.F., Mattingley, J.B., et al. Investigating the neuronal correlates of spatial attention in mice. *39th Annual Meeting of the Australasian Neuroscience Society*. Adelaide, Australia. 2-5 Dec 2019.
90. Eiber, C.D., Huang, J.Y., Belluccini, E.A., et al. Deploying iterative tomography for fast retinal receptive field mapping. *NeuroEng 2019: The 12th Australasian Workshop on Computational Neuroscience and Neural Engineering*. Adelaide, Australia. 29-30 Nov 2019.
91. Eiber, C.D., Huang, J.Y., Pietersen, A.N.J., et al. Visual receptive field mapping of linear and nonlinear responses using temporal decomposition and iterative tomography. *39th Annual Meeting of the Australasian Neuroscience Society*. Adelaide, Australia. 2-5 Dec 2019.
92. Faiz, A. Environment is a significant parameter in the switch between defensive behavioural responses. *39th Annual Meeting of the Australasian Neuroscience Society*. Adelaide, Australia. 2-5 Dec 2019.
93. Furlong, T., Merlin, S., Paxinos, G., et al. Dopaminergic lesions of the dorsolateral striatum prevent habitual actions resulting from extended training and L-dopa exposure. *39th Annual Meeting of the Australasian Neuroscience Society*. Adelaide, Australia. 2-5 Dec 2019.
94. Furlong, T., Merlin, S., Paxinos, G., et al. Habitual behaviour resulting from high-calorie food is prevented by an orexin-receptor antagonist. *International Behavioural Neuroscience Society Annual Meeting*. Cairns, Australia. 23-27 June 2019.
95. Furlong, T., Merlin, S., Paxinos, G., et al. Dopaminergic lesions of the dorsolateral striatum prevent habitual actions resulting from extended training and L-dopa exposure. *International Behavioural Neuroscience Society Annual Meeting*. Cairns, Australia. 23-27 June 2019.
96. Grünert, U., Nasir-Ahmad, S., Lee, S.C.S., et al. Non-classical ganglion cell types in primate retina. *European Retina Meeting 2019*. Helsinki, Finland. 12-14 Sep 2019.
97. Hasiuk, M., Pawar, K., Zhong, S., et al. Deep learning based motion estimation from highly under-sampled EPI volumetric navigators. *International Society for Magnetic Resonance in Medicine 27th Annual Meeting*. Montreal, Canada. 11-16 May 2019.
98. Henderson, J., Robinson, P.A. Transfer function synthesis of brain studies at the mesoscale and above. *NeuroEng 2019: The 12th Australasian Workshop on Computational Neuroscience and Neural Engineering*. Adelaide, Australia. 29-30 Nov 2019.
99. Jamadar, S.D. Functional connectivity in the ageing human maternal brain, and the neuroprotective effects of motherhood. *39th Annual Meeting of the Australasian Neuroscience Society*. Adelaide, Australia. 2-5 Dec 2019.
100. Jamadar, S., Li, S., Ward, P.G., et al. High temporal resolution resting-state metabolic connectivity using simultaneous BOLD-fMRI/FDG-PET. *2019 Organization for Human Brain Mapping Annual Meeting*. Rome, Italy. 9-13 June 2019.
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publications • presentations

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128.Schwenk, J., Zavitz, E., Vanarullen, R., et al. Neural correlates of perceptual echoes in marmoset primary visual cortex. *Neuroscience 2019*. Chicago, USA. 19-23 Oct 2019.

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137.Tekieh, T., McCloskey, S., Lockley, S.W., et al. Modelling melanopsin-dependent effects of light on circadian phase and alertness. *NeuroEng 2019: The 12th Australasian Workshop on Computational Neuroscience and Neural Engineering*. Adelaide, Australia. 29-30 Nov 2019.

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## CENTRE PROGRAMS

ECRs • education • the brain dialogue • neuroethics • neuroinformatics • equity & diversity • government, international & industry engagement

Centre programs

### Early career researchers



*Shivam Kalhan awarded second place in the three-minute fellowship competition.*

The framework of the Centre provides an unprecedented opportunity for ECRs to acquire multi-disciplinary expertise through collaboration with world renowned neuroscientists throughout Australia and the globe. In addition, the Centre's ECR program ensures Fellows and Scholars are offered an array of training and career development opportunities to foster career progression, ensuring the Centre is cultivating not just talented researchers, but the next generation of brain leaders.

Driven by the ECR Executive committee, the program offers a network of initiatives including one-on-one mentorship opportunities, funding for conference travel, funding to support lab exchanges, an annual interstate retreat, and career development workshops that are specific to the needs of the ECR cohort.

Members of the ECR Executive committee are elected at the beginning of each year for a 12-month term, with a representative appointed for each state in which a collaborating organisation is based (ACT, NSW, QLD, VIC). As representatives for their peers, it is the committee's responsibility to determine how to best utilise ECR funding for maximum benefit to the whole cohort in order to achieve their goals.

The 2019 ECR Executive Committee comprised Conrad Lee (ACT), Marilia Menezes de Oliveira (NSW), Cong Wang (QLD) and Molis Yunzab (VIC).

*"As a Centre of Excellence, one of our major goals is to advance the careers of outstanding early career researchers (ECRs)."*



# CENTRE PROGRAMS

ECRs • education • the brain dialogue • neuroethics • neuroinformatics • equity & diversity • government, international & industry engagement

## Mid-year retreat

One of the major events in 2019 was the annual ECR retreat. Over 20 ECRs (both fellows and scholars) were invited to Australian National University in Canberra to attend a two-day retreat featuring a packed program of tutorials, scientific talks, discussion panels and workshops.

Focusing on interaction with industry and science policies, the two-day retreat included professional development workshops on science communication, alternative career pathways, analytical skills, and seed funding opportunities. The ECRs in attendance were then offered the opportunity to present their scientific research, which was followed by brainstorming and discussion sessions to aid in the development of ideas as well as canvass potential collaborative opportunities.

In addition to the scientific and professional development program, the ECR Executive committee dedicated a portion of the program to workplace and personal wellbeing. The wellbeing of young researchers has been a recurrent theme of interest prioritised by the ECR cohort, and in response to that demand sessions were run to provide skills on achieving work-life balance. The retreat itself even included a yoga session in the scenic surrounds of ANUs Kioloa coastal campus.

The retreat was hugely successful with feedback from attendees overwhelmingly positive.



ECRs at their annual retreat held at ANU's Kioloa coastal campus.



Top: NSW based ECRs met for a social event, enjoying a cruise around Sydney. Above: Conrad Lee (ANU) pictured with Cong Wang (UQ) during his lab visit to the Sah lab at UQ.



# CENTRE PROGRAMS

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## End of year workshop

As in previous years, the first two days of the Centre’s annual meeting were dedicated to hosting the ECR workshop. Yet again, the ECR Executive committee designed a comprehensive program to both highlight scientific excellence of Centre fellows and scholars, and offered training and career development workshops.

Over 45 fellows and scholars attend the annual ECR workshop in Adelaide, which was themed around professional development in key areas of grant writing, presentation skills and work-life balance.

A mini-symposium was held, providing an opportunity for ECRs to present their research to practise their presentation skills, as well as gain feedback from the broad array of expertise present at the meeting. Emphasis then moved to preparation for the ECR Executive run three-minute fellowship competition. A workshop run by science communication expert Phil Dooley offered practical advice to help formulate ideas into a succinct proposal, before focussing on how to effectively and engagingly present their ideas within a three-minute window.

The final day of activities saw the focus change to wellbeing and work-life balance, with featured presentations from Yan Wong (setting up and establishing an independent research lab), Kylie Ball (how to be a balanced – and happy researcher), and Kathy Nicholson (how to define and live your work-life balance).

The ECR events concluded with the three-minute fellowship competition, held as part of the annual Welcome Dinner.

## Three-minute fellowship competition

As part of the 2019 program, the ECR Executive Committee allocated a portion of their funds to run a three-minute fellowship competition, as part of ECR events during the Centre’s annual meeting in Adelaide.

The competition was aimed at providing independent seed funding for ECRs to conduct a pilot experiment or a proof-of-principle study to improve the feasibility of an innovative idea that could form a grant application in 2020 or 2021. For this reason, the competition focused primarily on innovation, rather than feasibility and track record.

Hosted during the annual welcome dinner, participants were given three minutes to pitch their grant proposal, before being scored by a panel of judges on scientific quality, innovation, impact, feasibility and the integration of multiple disciplines. The audience was also given the opportunity to vote on a People’s Choice Award.

Winning both first place (\$8,000 research funding) and People’s Choice Award (\$250 voucher) was Monash student Winnie Orchard with her study ‘Neural Adaptations of the Post-Partum Year (NAPPY)’. University of Queensland student Shivam Kalhan was awarded second place (\$5,000 research funding) for his study ‘Neural Correlates of belief modulation: Ameliorating impulsivity in addiction’, and in third place (\$3,000 research funding) was Brandon Munn from the University of Sydney with his study ‘Efficient real time suppression of parkinsonian states via closed loop deep brain stimulation’.

## ECR Travel Awards

The ECR Executive Committee organised two rounds of travel awards during 2019, funds of which facilitated travel that benefited ECRs’ research and/or careers. Applications were competitively judged, and a total of 10 ECRs were awarded over \$8,000 collectively to travel to international and national conferences.

Coordinating scientific and professional development programs designed to appease a vast array of scientific fields and career levels can be a challenging one, and for that, the 2019 ECR executive committee have to be commended on the success of their events throughout the year.

“Over 45 fellows and scholars attended the annual ECR workshop held in Adelaide, which was themed around professional development in key areas of grant writing, presentation skills and work-life balance.”



Left: Winnie Orchard awarded 1st place in the three-minute fellowship competition, right: Science communicator Phil Dooley presenting at the ECR workshop in Adelaide.



Top: ECRs working at their annual retreat held at ANU’s Kioloa coastal campus. Above: CIBF ECRs Ehsan Kheradpezhoh (ANU), Roger Marek (UQ), Sam Marlin (UWS), Teri Furlong (UNSW)



# CENTRE PROGRAMS

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## Education

### Secondary schools

#### Australian and New Zealand Brain Bee Challenge

The Centre once again hosted the 2019 Australian and New Zealand Brain Bee Challenge, coordinated centrally by Centre AI Professor Ramesh Rajan. The Brain Bee Challenge is an annual neuroscience competition for students in year 10 in Australia and in year 11 in New Zealand, which encourages students to learn about the brain, aiming to inspire students to pursue brain-related careers in medicine and research.

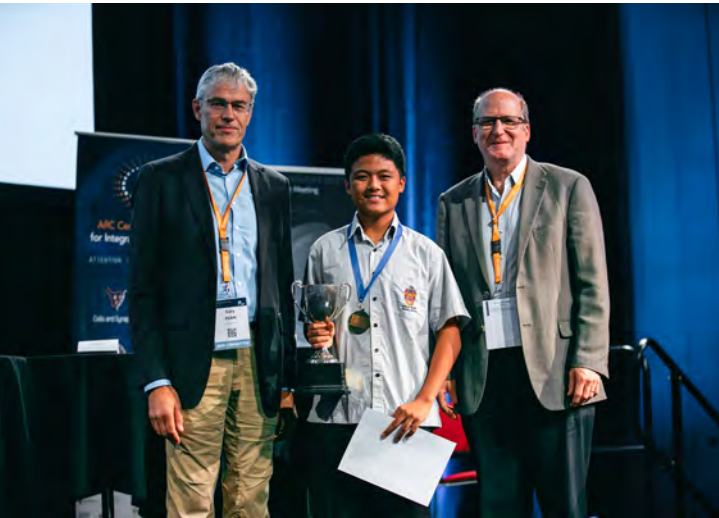
The competition takes part in three stages, beginning with an online quiz held during Brain Awareness Week in March. This initial stage is managed by partner Education Perfect, with top-performing students invited to participate in regional finals organised by the Brain Bee's state coordinators. One winner is awarded from each regional competition, all of whom progress to compete in the national finals held at the Australasian Neuroscience Society's annual meeting.

As in previous years, the National finals were extremely competitive, with Peter Susanto (Haileybury Rendall School), the first ever winner from the Northern Territory taking out the Australian competition, and Jacob Lee from NSW (Carlingford High School) awarded runner-up. The New Zealand winner was Xiaojian Guo from the North Island (ACG Parnell College) and coming in as very close runner-up was South Island's Katie Harris (Nelson College for Girls).

Both National winners will be flown to Washington D.C., USA, to compete internationally in the Brain Bee World Championship, which will take place on August 6-9 2020, in conjunction with the American Psychological Association Annual Convention.



Brain Bee 2019 national finals hosts (left) and winner Peter Susanto from Haileybury Rendall School (right).



### Brain Bee World Championship

Winners of the 2018 Australian and New Zealand Brain Bee Challenge, Silas Hansch-Maher (Aus) and Sophia Ye (NZ) were flown to Daegu, South Korea, to compete in the 2019 Brain Bee World Championship. The competition took place as part of the International Brain Research Organization (IBRO) World Congress of Neuroscience, in September 2019.

Both representatives performed exceptionally, with Sophia coming 4th, and Silas Hansch-Maher placing 5th from a field of 28 international competitors.



Australia's representative Silas Hansch-Maher awarded 5th place at the International Brain Bee Challenge, South Korea.



New Zealand representative Sophia Ye awarded 4th place at the International Brain Bee Challenge, South Korea.



Student competitors at the International Brain Bee Challenge; hosted by the International Brain Research Organisation World Congress (IBRO) in Daegu, South Korea.



# CENTRE PROGRAMS

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## Primary schools creative art competition

The Centre continued its successful neuroscience drawing competition as part of Brain Awareness Week, 11–17 March 2019. Brain Awareness Week is a global campaign, led by The Dana Foundation, which aims to increase awareness of the importance and current state of brain research in the world.

Primary school students from around Australia were invited to submit creative artworks that showed ‘Why their brain is amazing...’. We received a record number of entries (1,200+) across three categories.

Drawings were shortlisted by a panel of judges, prior to opening voting to all Centre members. Over 100 Centre staff and students voted for their favourite drawings, awarding 1st, 2nd and 3rd prizes in each category.

All winners received a prize pack containing brain-related books, activities, puzzles and games, with each winner’s school receiving a brain-related resource pack and a voucher to purchase additional educational resources.

Beyond the vouchers and prizes, the 1st place winners were treated to a special visit by Centre researchers to award their prizes in person, and delivered an age-appropriate interactive educational lesson about the brain to the winner’s class.

The student artworks have been so well received that many have been placed on display around the Centre Nodes. Expanding on this opportunity with the aim of sharing our resources with the general public, a selection of these works have been included in a public exhibition that has been displayed throughout several public libraries and will continue to tour for the foreseeable future.

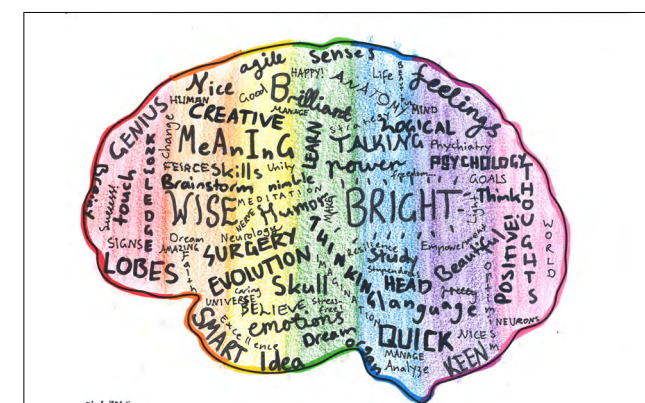
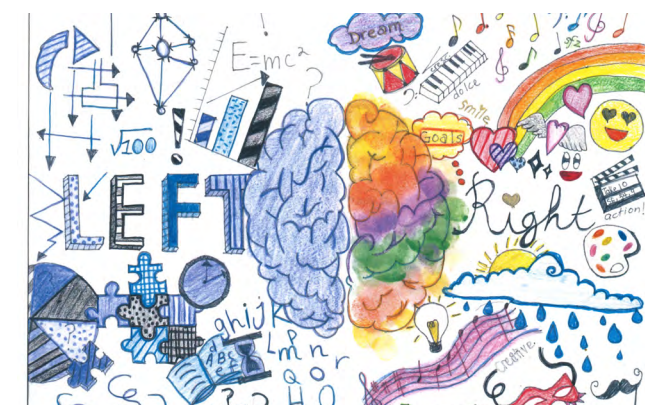
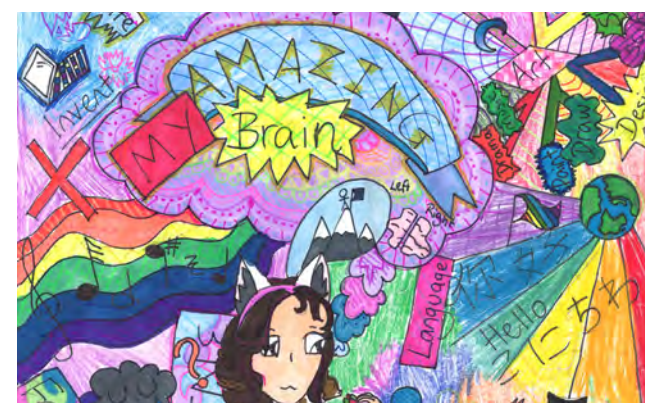
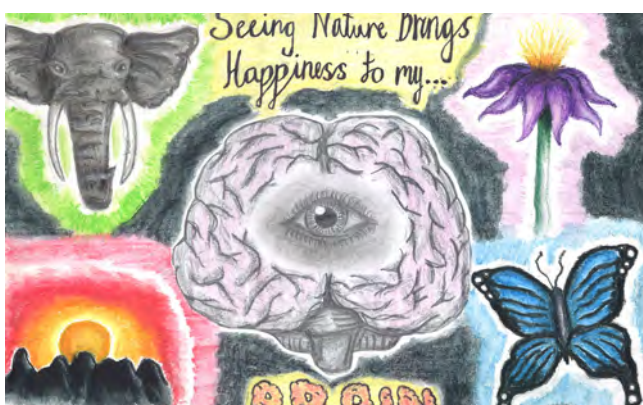
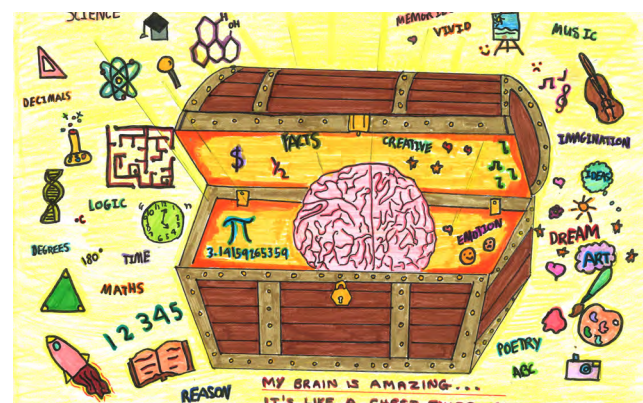
**Category 1:**  
Foundation  
year (Prep)  
and Year 1  
(ages 5–7)



**Category 2:**  
Years 2–4  
(ages 7–10)



**Category 3:**  
Years 5–6  
(ages 10–12)



“Primary school students from around Australia were invited to submit creative artworks that showed ‘Why their brain is amazing...’. We received a record number of entries (1,200+) across three categories.”



# CENTRE PROGRAMS

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## The Brain Dialogue

The Brain Dialogue is a public engagement platform that aims to maximise the social, economic and scientific benefits of brain research. Our goal is to facilitate knowledge sharing in order to strengthen connections between our researchers and end users.

This is achieved by engaging with:

- the Australian public - to keep them abreast of the rapid progress in brain research and the issues and opportunities it offers;
- investigators - who benefit from insight into end users' needs and aspirations, allowing them to better align their research with public needs;
- industry - that benefits from understanding the Centre's interests and capabilities, with the ambition to develop collaborative opportunities.



Matt Davidson – 16 hours ago  
@BrainDialogue @jbmattingley @QldBrainInst @arc\_gov\_au @BrainAllianceAu @AusNeuroSoc @Science\_Academy @AusSMC...  
<https://t.co/sWlx49V3hx>

ANS Australasian Neuroscience Society – 17 hours ago  
New research! A new method for measuring rapid brain activity helps to explain why our brains can't process many t...  
<https://t.co/2kbnMiW4eX>

Wayne State Neuroscience – 17 hours ago  
It's #BrainAwarenessWeek - a global campaign to foster public enthusiasm and support for brain science. Each year w...  
<https://t.co/H0iPmhLqPS>

Queensland Brain Institute, UQ – 22 hours ago  
New research! A new method for measuring rapid brain activity helps to explain why our brains can't process many t...  
<https://t.co/2kbnMiW4eX>

Anthony Hannan – 22 hours ago  
A great story by @BrainDialogue of how the GABA discovery was made & what it means for #neuroscience: ...  
<https://t.co/1IKGER6s7U>

ADSG – 22 hours ago  
It's #BrainAwarenessWeek - a global campaign to foster public enthusiasm and support for brain science. Each year w...  
<https://t.co/H0iPmhLqPS>

Dr M S Krishnan – 23 hours ago  
It's #BrainAwarenessWeek - a global campaign to foster public enthusiasm and support for brain science. Each year w...  
<https://t.co/H0iPmhLqPS>

Stacey Auger – 1 day ago  
Quick - Notify the Whitehouse!  
<https://t.co/vnANWdXJv>

Monique Mortlase – 1 day ago  
It's #BrainAwarenessWeek - a global campaign to foster public enthusiasm and support for brain science. Each year w...  
<https://t.co/H0iPmhLqPS>

Dana Foundation – 1 day ago  
It's #BrainAwarenessWeek - a global campaign to foster public enthusiasm and support for brain science. Each year w...  
<https://t.co/H0iPmhLqPS>

The Brain Dialogue – 1 day ago  
Thanks @qldscience for supporting our art competition and promoting #BrainAwarenessWeek! @dana\_fdn #BrainDialogue  
<https://t.co/bfjXmT0vqf>

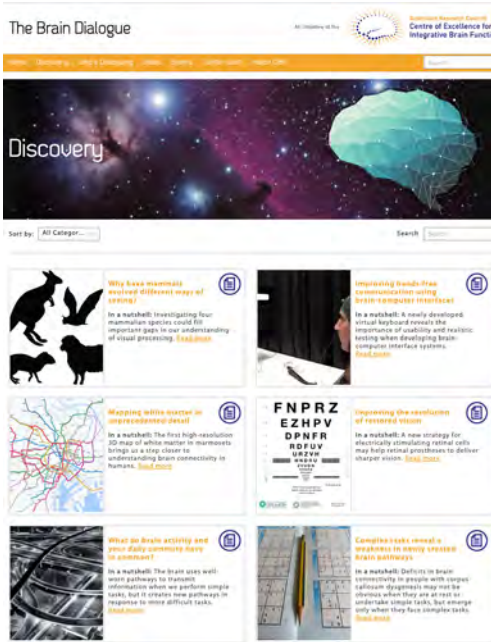
The Brain Dialogue – 1 day ago  
New research! A new method for measuring rapid brain activity helps to explain why our brains can't process many t...  
<https://t.co/2kbnMiW4eX>

### Plain language summaries

One major goal of the Brain Dialogue is to share Centre research publicly in a format easy to comprehend by the general public, to ensure everyone can access and benefit from our findings. Our Discovery section presents Centre research outcomes 'In A Nutshell', that explain publications and their significance in plain English. Making our research accessible in this way not only informs the broader community as to what the Centre does, but also opens up opportunities for interdisciplinary research and linkage within the scientific community and industry.

To encourage knowledge sharing, content produced by the Brain Dialogue is published under a Creative Commons Attribution 4.0 International (CC BY 4.0.) license. This means that anyone can adapt and reuse the content, including for commercial purposes.

In 2019, we wrote and published a total of 18 plain language summaries which were shared across all our social media platforms. This not only enhanced the reach of our findings, but also increased Altmetrics for our researchers leading to additional republication through social media channels, and often meant these findings were re-published by additional media outlets.



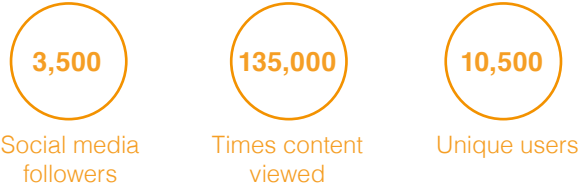
### Social Media

An integrated web and social media presence allows unrestricted access and reuse of our research content, maximising the impact of our resources and providing linkages to the public, broader scientific community and industry, both Australia wide and globally.

The Brain Dialogue Facebook and Twitter pages provide followers with curated content about new discoveries in brain research from the Centre, as well as the world's top journals and news outlets. With a combined following of over 3,500 users, our content was viewed 135,000 times, by over 10,500 unique users throughout 2019.

The success of the Centre's social media knowledge sharing strategy can be seen with the increased Altmetrics scores of all published research, averaging 12.46, with nine articles being ranked in the top 5% of all research outputs to be scored by Altmetric in 2019.

With all content published using the COPE (Create Once, Publish Everywhere) strategy, we have ensured our research is promoted in such a way as to reach the broadest possible audience across both public and scientific communities.





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At the 'Brain Control' event from L-R: Jon Faine (host), Dr Jamie Walvisch (Monash University organiser), A/Prof Adrian Carter (Monash University organiser) and panellists Prof Judy Illes, Vrinda Edan, Sven Bluemmel and Prof Mark Andrejevic.

## Neuroethics

The Neuroethics Program has had an outstanding year that has built on the Centre's long-standing commitment to understanding the ethical and social impact of cutting-edge neuroscience on Australian society.

Neuroethics is an internationally recognised field that aims to successfully translate brain research in ways that maximise social benefit while minimising harms. The need for Neuroethics has been recognised by all major brain projects around the globe, including the US BRAIN initiative and EU Human Brain Project, and other brain initiatives in Japan, Korea, China, Canada and Australia.

The Brain Function CoE has led numerous national and international neuroethics activities throughout 2019, creating opportunities for collaboration and advancement in the field. The Australian Neuroethics Network, an interdisciplinary network created by the Centre, now has over 150 members who work to foster neuroethics through research, public outreach and other activities. The Australian Brain Alliance has made Neuroethics a key priority for the Australian Brain Initiative. The leadership of the Centre in this area has greatly facilitated this development.

### 2019 Neuroscience and Society Conference

In December, the Centre's Neuroethics Program, in partnership with the Australian Neuroethics Network, the Turner Institute for Brain and Mental Health at Monash University, the Law, Health and Wellbeing Group at the Monash University Faculty of Law, and the International Neuroethics Society held their third annual two-day conference.

'NEUROFUTURES: Neuroscience and Responsibility' was another successful event with over 90 registrants from government, law, health, academia, and industry. This was the first time that the conference was held in Melbourne. The event included 11 international speakers, and keynote presentations from Judy Illes (University of British Columbia), Jennifer Chandler (University of Ottawa), Joan Leach (Australian National University), and Julian Savulescu (University of Oxford).

The conference program focused on a wide range of ways in which neuroscience can invoke responsibility and featured exciting scientific, ethical, philosophical and legal lectures and discussions on the theme of 'Neuroscience and Responsibility'. This included a number of keynote, symposium, panel and lightning presentations on the following topics:

- Neuroscience and Public Health
- Neurointerventions
- Neuroscience in the Courts
- Digital Health
- Animal Models
- Criminal Responsibility
- Agency and Responsibility

### Public Engagement

The Neuroethics Program published an article on the current state of neurotechnology regulation in The Conversation in the lead up to the Neuroscience and Society Conference, "Stimulus package: brain stimulation holds huge promise, but is critically under-regulated", that attracted over 5,500 views.

Furthermore, the Centre was pleased to host a number of free events on the impact of neuroscience.

As part of the Centre's ongoing commitment to dialogue about the brain and the self, the Neuroethics Program launched the paperback edition of Dr Tamara Kayali Browne's book "Depression and the Self: Meaning, Control and Authenticity". This free event featured Dr Browne (Deakin University) in conversation with Professor Cordelia Fine (Melbourne University) at the Monash Law Chambers.

The Neuroethics Program, in collaboration with the Australian Neuroethics Network and Monash University, also hosted a free public event at the State Library of Victoria in December; 'Brain Control: The impact of science and technology on our mental health, law and privacy'. This event received over 400 registrations. The panel was hosted by ABC radio personality Jon Faine, and the panellists were Mr Sven Bluemmel (Victorian Information Commissioner), Professor Judy Illes (University of British Columbia), Professor Mark Andrejevic (Monash University) and Vrinda Edan (Victorian Mental Illness Awareness Council). These expert panellists discussed the virtues and risks of our digital health data being captured and used by others in the age of Facebook, metadata retention laws, Cambridge Analytica and a rapidly evolving neuroscience. You can watch the event on YouTube.

### International Engagement

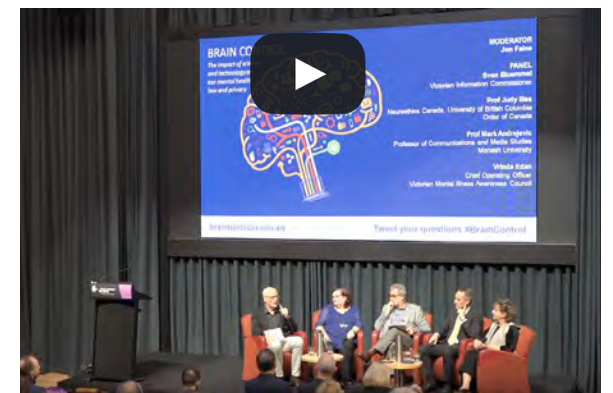
A/Prof Adrian Carter represented Australian neuroethics and the Brain Function CoE at the 2019 Annual Meeting of the International Neuroethics Society in Chicago at a panel discussion on 'Dilemmas in Global Neuroethics'. A/Prof Carter also participated in the Global Neuroethics Summit in Uppsala, Sweden on community engagement in neuroethics. A/Prof Carter was also elected to the Board of Directors for the International Neuroethics Society and has accepted an invitation to Chair the Program Committee for the 2020 International Neuroethics Society Meeting in Washington prior to the Society for Neuroscience meeting. These events highlight the well-deserved international recognition of the Centre's leadership in neuroethics in Australia and our success in fostering local researchers.

### Growing Interdisciplinary Research

In 2020, The Neuroethics Program is looking to expand its Embedded Neuroethics Research program. This program allows students and ECRs from bioethics, law, philosophy or social science to spend short visits at a neuroscience laboratory relevant to their research. We now have three placements available for researchers to intern within a neuroscience laboratory at the Brain Function CoE. This is the first program of its kind in Australia and will pave the way for further interdisciplinary collaborations.

#### Discover more about our Neuroethics program

Brain Control: The impact of science and technology on our mental health, law and privacy





## Neuroinformatics

The Centre's neuroinformatics program supports Centre researchers by providing access to high-performance data processing and advanced analysis and visualisation resources; supporting the development and publication of software tools and datasets; and building partnerships with international neuroinformatics infrastructure initiatives.

The Centre is the Australian Node (and a Governing Node) of the International Neuroinformatics Coordinating Facility (INCF), an international non-profit organization devoted to advancing the field of neuroinformatics and global collaborative brain research.

As the Australian node, the Centre works with Australian eResearch organisations, including the MASSIVE high-performance computing facility, to provide neuroinformatics research services to Australian neuroscientists. The INCF Australian node represents Australian neuroinformatics efforts and promotes and prioritize neuroinformatics on a national scale, including working on the development of tools and best practice for the storage, sharing and publishing of imaging data. The Australian node works with INCF globally to foster scientific collaboration, advancing training and coordinate the

global development of neuroinformatics. The Australian Node is a Governing Node of the INCF and is represented on the INCF Governing Board (voting Deputy Chair), Council for Training, Science and Infrastructure (2 voting members) and Infrastructure Committee (Chair).

As a direct result of the partnership between the ARC Centre for Integrative Function and MASSIVE, neuroscience has grown to become the largest user community on the MASSIVE high-performance computing facility. As of December 2019, 104 individual neuroscience research projects across Monash University, University of Queensland, University of Sydney, and Queensland Institute of Medical Research, and other sites, are using the MASSIVE facility for data processing and modelling.

The Australian node to host 2020 Neuroinformatics Assembly in Seattle in August 2020, with the Allen Institute for Brain Science as co-host organisation. Centre members Prof Marcello Rosa, Dr Wojtek Goscinski and Dr Ben Fulcher are on the organising committee.



*Gender, Equity and Diversity Committee at their annual face-to-face meeting in Adelaide. From L-R: Dr Teri Furlong, Prof Melinda Fitzgerald (Chair), Masha Perry, Dr Sharna Jamadar, Dr Nic Price*

*The 2019 Committee comprised Prof Melinda Fitzgerald (WA), Prof Michael Ibbotson (VIC), Dr Teri Furlong (NSW), Dr Nic Price (VIC), Dr Sharna Jamadar (VIC), Dr Phillip Ward (VIC), Dr Ilvana Dzafic (QLD) and Masha Perry (VIC).*

## Equity and Diversity

**Our Centre is committed to creating an environment where all staff and students are equally respected and valued and enjoy equity of both opportunity and outcome.**

The Centre is passionate about the growth and future of brain research in Australia. Key to this aim is training, supporting and promoting the next generations of researchers and scientific leaders through the early and mid-stages of their career, irrespective of background, culture, age, gender, religion, disabilities or sexual orientation.

The Centre's Gender, Equity and Diversity Committee (GEDC) consists of volunteers from both outside and within the Centre, including Chief Investigators and early and mid-career researchers, who develop initiatives and formalise policies to improve gender balance, equity and diversity in the Centre. The Committee is grateful to strong contributors Dr Nic Price and Dr Phillip Ward who stepped down from the committee in 2019.

The following outcomes arose from the GEDC's activities in 2019.

- Unconscious bias training was provided by Dr Jennifer Whelan, the Founder and Director of Psynapse Psychometrics Pty Ltd, to all attendees at the Centre's Annual General Meeting in Adelaide in December.
- English as a second language has remained a focus of the Centre throughout 2019 and resources have been updated to ensure links for assistance are available to Centre members.
- Caregiver Travel Grant: the definition of primary caregiver is now less relevant; therefore, the Committee adjusted the terms and details of the caregiver grant accordingly. The Committee awarded seven caregiver travel grants in 2019, providing a total of \$3,719.
- Enhancing Diversity: The Committee have considered options to assist in attracting and retaining international post-docs. With this mind, policy guidelines, accessibility guidelines, and links for assistance for people for whom English is a second language have been updated.



CENTRE PROGRAMS

ECRs • education • the brain dialogue • neuroethics • neuroinformatics • equity & diversity • government, international & industry engagement

Government, International and Industry Engagement

Australian Brain Alliance

In 2019 a number of Centre Chief and Associate Investigators continued to have leadership roles in the Australian Brain Alliance, a consortium of research institutes, higher education providers, and business leaders in the brain science and technology industry brought together under the auspices of the Australian Academy of Science. The Centre thus continued to have a significant voice in the ABA’s work to establish priorities for investment and to build Australia’s brain research projects and capabilities into a truly national endeavour with impact on a global scale.

The Centre provided administrative support in 2019 to the ABA Executive in the development of a strategic business case for public investment in a national brain science and industry initiative, the proposed Australian Brain Initiative (ABI). Members of the Australian Brain Alliance Executive met with 17 parliamentary offices over two days on October 14 and 15 as part of Brains on the Hill activities. This targeted approached leveraged off the extensive parliamentary engagement of 2018. The Business Case for an ABI was launched at an evening function on October 14. Speakers at the launch included the Honourable Brendan O’Connor (Shadow Minister for Employment and Industry), Australia’s Chief Scientist, Dr Alan Finkel, AAS CEO Ms Anna-Maria Arabia and ABA co-chair, Professor Linda Richards. We anticipate the Centre will work closely with the ABA to build on these activities further in 2020.



Australian Brain Data Commons

In 2019 a Working Group of stakeholders representing a range of academic research disciplines in the neurosciences and the private sector was established to determine the requirements for a coordinated and internationally compatible national brain science data framework. The Australian Brain Data Commons (ABDC) Working Group includes Centre members and alumni representing the Australian node of the INCF and the Executive Committee of the Australian Brain Alliance, along with researchers with expertise in data infrastructure, cognitive neuroscience and psychology, MRI/PET/molecular imaging (human and animal), EEG/MEG, animal behaviour/neuroethology data, microscopy, histology and gene expression, molecular neuroscience, electrophysiology and calcium imaging, neurogenomics and clinical data, computational neuroscience, and AI/machine learning.

The ABDC Working Group terms of reference were developed and specified the following objectives:

- 1. To map current data sharing standards in neuroscience research used by Australian laboratories.
- 2. To convene workshops and meetings to provide a forum for discussion and consensus building around identifying the infrastructure, technical and human resources required to develop a culture in Australia of neuroscience data standards and sharing that satisfies the FAIR principles.
- 3. To educate the neuroscience community on how to re-use data for maximum benefit and to promote and support data sharing and standards implementation in the neuroscience sector in Australia.
- 4. To provide a representative group for information sharing and international collaboration via the International Brain Initiative and other appropriate international organisations.
- 5. To provide advice, via the Australian Brain Alliance, to the Australian Research Data Commons and Australian Government on issues related to neuroscience data standards and sharing.

The Working Group compiled information on current data standards and data sharing practices in Australia, as well as the range of software platforms used in Australia for data sharing in the different neuroscience sub-disciplines. Assessments were made of the national barriers that prevent wider adoption of FAIR data sharing. The Working Group also co-convened a national symposium on Data sharing: neuroscience, microscopy and experiments, which was held on the 9th of October 2019 in Canberra.



# DATA SHARING:

## Neuroscience, Microscopy and Experiments Collaborative Symposium

### Speakers and Invited Guests

A combined symposium to plan how we enable interoperability and collaboration between researchers in a data-driven world.

**Prof Alan Evans**  
Director of the McGill Centre for Integrative Neuroscience, McGill University

**Prof Jason Swedlow**  
Director of the Open Microscopy Environment, University of Dundee

**AProf Kaylene Simpson**  
Senior Editor of Nature Scientific Data, Peter MacCallum Cancer Centre

**Dr Shawn Brown**  
Associate Director for Research Software Development, McGill University

**Prof Giorgio Ascoli**  
Center for Neural Informatics, Structures, and Plasticity, George Mason University

**David Orloff**  
Director of the Cell Image Library, University of California at San Diego

**AProf Claire Brown**  
Director of the Advanced BioImaging Facility, McGill University

### Event Workshops

**Australian Characterisation Informatics Planning Workshop**

Characterisation has become an area where informatics infrastructure, expertise and best practice is critical. The Australian Characterisation community shares a number of significant informatics challenges, and the community is working together to plan and implement strategies to overcome these challenges. This workshop will bring together Australian and International experts to map the strategic links between characterisation facilities, informatics standards and best practices, and research communities, with the overall goal of planning for the future.

**Australian Neuroscience Microscopy Data Sharing, Standards and Best-Practice Workshop**

Recent advances in optics, computational tools and automation have increased the impact of modern optical microscopy not only in basic science but also in industry and clinical domains. The Australian optical microscopy community is actively working together to form a dynamic network of researchers who will enable data sharing and standardisation. The aim of this initiative is to increase the quality and reproducibility, and boost the overall value of optical microscopy data. This symposium will discuss the current challenges of data sharing and protocols with the aim of mapping out a national strategy to integrate current systems into a unified Australian data sharing platform.

**Australian Brain Data Commons Workshop**

By its very nature, the brain is at the core of who we are and cracking its “code” (how it works) is one of the greatest scientific challenges facing humanity. To crack the brain’s code neuroscience has become one of the most highly interdisciplinary scientific research disciplines. Understanding the brain’s code – the neural circuits and processes underlying cognition – is currently at the forefront of brain research nationally and internationally. Central to cracking the code will be a national strategy for brain research data sharing and curation. This workshop will bring together brain researchers and neuroinformaticians to map the national brain data commons capabilities, review the community requirements, and develop a national plan for neuroscience data sharing and curation.

**9th October 2019**

**The Shine Dome Canberra**

**Registration**  
<https://bit.ly/2lm7gdw>  
Registrations close  
COB Monday 7th October

**Schedule**  
Registration from 8:30am  
Opening and invited speakers from 9am  
Workshops from 1pm  
Combined discussion and social from 4pm

**Organising Committee**  
Prof Linda Richards  
Prof Tony Hannan  
Dr Nela Durisic  
Dr Rumelo Amor  
Dr Khaled Chakli  
Dr Paula Martinez Villegas  
Dr Wojtek James Goscinski



ARC CoE FOR INTEGRATIVE BRAIN FUNCTION

Annual Report 2019



# EVENTS

centre events • sponsored events

## Events



### Public Events

#### Brain Control: The impact of science and technology on our mental health, law and privacy

Collaborating with the Neuroethics Network and Monash University, the Centre presented a free public event as part of the 2019 Neuroscience and Society Conference.

Held in Melbourne at the State Library of Victoria, the event brought together leading international and national scientists, ethicists, lawyers and marketing and communication experts to discuss the ethical implications of health metadata, how it's continuously captured by smartphones and other wearable devices, where it's stored, and who could potentially access it.

The discussion led by ABC radio personality Jon Faine included panellists Sven Bluemmel (Victorian Information Commissioner), Professor Judy Illes (University of British Columbia), Professor Mark Andrejevic (Monash University) and Vrinda Edan (Victorian Mental Illness Awareness Council).

Following the panel discussion, the audience were welcomed to ask questions, and debate the ethical implications and risks associated with digital health data being captured and used by others in the age of Facebook, metadata retention laws, Cambridge Analytica and a rapidly evolving neuroscience. Key questions included: who collects and has access to our data?, should we be informed of what is done with our data?, is our privacy at risk?, could data be used to discriminate against vulnerable populations?, and how might our data be used by third parties such as educators, insurers, employers and courts?

The event was a huge success, presented to a sell-out crowd, and in addition, has been made publicly available via YouTube.

#### International Workshop - Masterclass in fundamental neuroanatomy

Together, Centre Associate Investigators Alex Fornito and Charles Watson coordinated an international workshop on neuroanatomy. Open to Centre members and the wider neuroscience community, the workshop was given by world-renowned neuroanatomist, Emeritus Professor Luis Puelles, from University of Murcia, Spain.

The four-day workshop addressed Neuromorphology, emphasising fundamental concepts (brain axis, anteroposterior and dorsoventral dimensions, sorts of subdivisions, patterning mechanisms at neural plate and neural tube stages), the neuromeric model, more detailed partial brain models (hindbrain, midbrain, diencephalon, hypothalamus, subpallium, pallium) and practical examples of basic morphologic analysis applied to embryonic or adult mouse brains.

The event was a sell-out, filling all 30 places and attracting registrants from Australia, Italy, France and the USA.

"The event was a huge success, presented to a sell-out crowd, and in addition, has been made publicly available via YouTube".



## Centre Meetings

### Mid-Year Science Meeting

To facilitate communication and research integration, Centre CIs, AIs and Senior Fellows were invited to the ANU in Canberra to attend the annual mid-year science meeting. The two-day meeting comprised a scientific program focusing on neural modelling of brain function, multiscale mechanisms of higher brain function, cellular mechanisms of higher brain function, neural circuits of integrative brain function and predictive coding.

In addition to the scientific program, Centre members gathered to discuss and plan for the future, ensuring the centre's legacy will continue beyond the conclusion of centre funding.

The meeting was highly productive, driving several new collaborative Special Initiative Project proposals, engaging both AIs and ECRs into these projects.

“Our Annual General Meeting included a special ‘Unconscious Bias’ interactive workshop delivered by Dr Jennifer Whelan from Psynapse Consulting.”

### AGM and Science Meeting

The Centre's sixth annual meeting held in December in Adelaide was the biggest and most successful to date, bringing together over 100 Centre CIs, AIs, Board members, Fellows, Scholars and Administrators over the course of three days.

Beginning with ECR activities which included a mini symposium, mentorship discussions and workshops on wellbeing, career sustainability, and presentation skills to prepare them for the three-minute fellowship competition.

Our Annual General Meeting (AGM) followed, which included highlights from the Centre's outreach programs, followed by a special ‘Unconscious Bias’ interactive workshop delivered by Dr Jennifer Whelan from Psynapse Consulting.

The Welcome Dinner included excellent presentations from the ECR three-minute fellowship competition entrants, honing their communication skills in a bid for research funding. Audience involvement was at a high, with all attendees given the opportunity to vote for a people's choice award, in addition to the panel awarding prizes to the top three presenters.

The Science Meeting ‘How the Brain Interacts with the World’ organised by Elizabeth Zavitz, Saba Gharaei, Paul Martin and Jason Mattingley, once again highlighted outstanding brain research from both Centre members and external researchers. The program featured sessions on plasticity, sensation and perception, and vision and brain technologies, with a keynote presentation given by University of Otago's Cliff Abraham (NZ).

The entire three-day program was a massive undertaking, however the involvement and contribution from all attendees made it a tremendous success. We are thankful that each year the Centre grows, and so too does the commitment of our researchers and support staff.

*Facing page images, clockwise from top: Centre members gathered for the annual welcome dinner during end of year events in Adelaide; AGM Workshop; Science Meeting; Attendees at the 2019 Science Meeting ‘How the Brain Interacts with the World’ held at the Adelaide Convention Centre.*





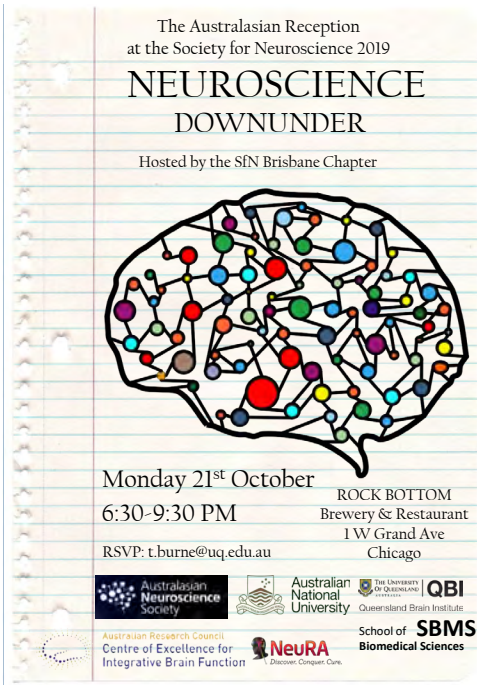
# EVENTS

centre events • [sponsored events](#)

## Workshop: Maths in the Brain

This workshop, sponsored by the Brain Mapping and Modelling Research Program of Turner Institute for Brain and Mental Health, in partnership with our Centre, presented Monash researchers (faculty, postdocs, students) working in all domains of science, an opportunity to engage with experts working in this exciting and rapidly developing area of research in September 2019. The workshop brought together Monash researchers with a shared interest in understanding the brain from a quantitative perspective.

It was an extremely successful event beyond our expectations. The workshop was fully booked within days and capacity was increased to meet the high demand. Leading Monash researchers presented their latest work on mathematical modelling of brain structure and function, mapping and modelling of how disease affects the brain, and how coordinated brain function gives rise to perception and cognition. The invited speakers represented a very wide range of disciplines from Physics, Engineering, Mathematics, Information Technology, Psychology, Neuroscience, Philosophy, and Physiology highlighting the cross-disciplinary appeal of the workshop.



University Laval (Quebec), The University of Dublin, Wilfred Laurier University, National Institutes of Health, University of Massachusetts Medical School, the University of Guelph and Linköping University (Sweden).

Brain Function CoE funds helped to support the venue and catering to facilitate networking and engagement. Our sponsorship was instrumental in facilitating an internationally successful collaborative function and networking opportunity for a large number of early career researchers, PhD students, mentors and colleagues in neuroscience. The SfN Brisbane chapter is grateful for the generous support provided by the Centre.

## Neuroscience Downunder

This year, the Brisbane Chapter hosted the Neuroscience Downunder mixer event as part of the Society for Neuroscience (SfN) annual conference in Chicago in October 2019. This is an annual event hosted each year by a different Australian chapter of the Society for Neuroscience. The event attracted over 100 neuroscientists from around the world and provided an excellent opportunity for networking and engaging with Australian, New Zealand and US based neuroscientists. The event attracted neuroscientists from a wide range of Australian institutions, including: The University of Queensland, the University of Newcastle, the University of New South Wales, the Florey Institute, Macquarie University, La Trobe University, Walter and Eliza Hall Institute, Australian National University, the University of Melbourne, Queensland University of Technology, the University of Sydney, Deakin University, and the University of Western Sydney.

We were also able to attract a number of neuroscientists from a wide range of International institutions, including: University of Otago, The University of Auckland, Rutgers University, University of California, Irvine, The University of Chicago, University of California, Los Angeles,



## NeuroEng 2019

NeuroEng 2019, the 12th Australasian Workshop on Computational Neuroscience and Neural Engineering, was hosted by the University of Sydney in November. The meeting was held as a satellite of the Australian Neuroscience Society (ANS) Conference, both held in Adelaide.

The event brought together computational neuroscientists and researchers at the interface between neuroscience and engineering. It was well attended with around 70 registrants, including 23 students. The meeting consisted of 29 speakers, two poster sessions and a panel session. The workshop not only allowed for the presentation of scientific material, but also was a valuable opportunity for scientific discussion and networking.

Without the support of sponsors like the Brain Function CoE, the NeuroEng meeting simply could not exist. Centre funding was dedicated to supporting one of the two international keynote speakers, Professor Barbara Webb from the University of Edinburgh.

## 2019 Whistler-Noosa Summer Workshop on Brain Functional Organisation, Connectivity and Behaviour

This biennial workshop, organised by Yale University, has been running over the past eight years and attracts some of the leading figures in human and animal brain imaging. The meeting was held in Noosa, QLD in March 2019 and going forward will be held in Australia every other year.

The conference was a major success. Attendance was at full capacity, with over 70 delegates. Critically, the majority of attendees were from overseas. The Workshop attracted major international researchers in neuroimaging to Australia. The only prior time that so many high-calibre researchers

in neuroimaging were in Australia at the same time was for the 2008 Organization of Human Brain Mapping meeting in Melbourne.

The conference provided an invaluable opportunity for local researchers to present their work and interact with prominent international scientists. It also provided Australian researchers with an update on the latest tools, techniques, and concepts being used in neuroimaging.

Sponsorship from the Centre was used to cover the expenses of the conference dinner. This was a major success and provided an invaluable opportunity for all delegates to interact both socially and scientifically.

## Australian Course in Advanced Neuroscience

The Australian Course in Advanced Neuroscience (ACAN) was held at the University of Queensland Moreton Bay Research Station from the 5-25 May 2019. There were 48 applications for the 14 places on the course. This year more attention was paid to the teaching of the principles of behavioural neuroscience, and featured lecturers and hot topics which integrated cellular, behavioural and systems neuroscience. Each of the experimental days was a success and the students, without exception, were able to obtain results and develop their experimental skills on a daily basis.

Centre funding contributed to support the rental of laboratories and travel for instructors, with such funding being central to the ongoing viability of the course.

## The Australian Chapter of the Organization for Human Brain Mapping (OHBM)

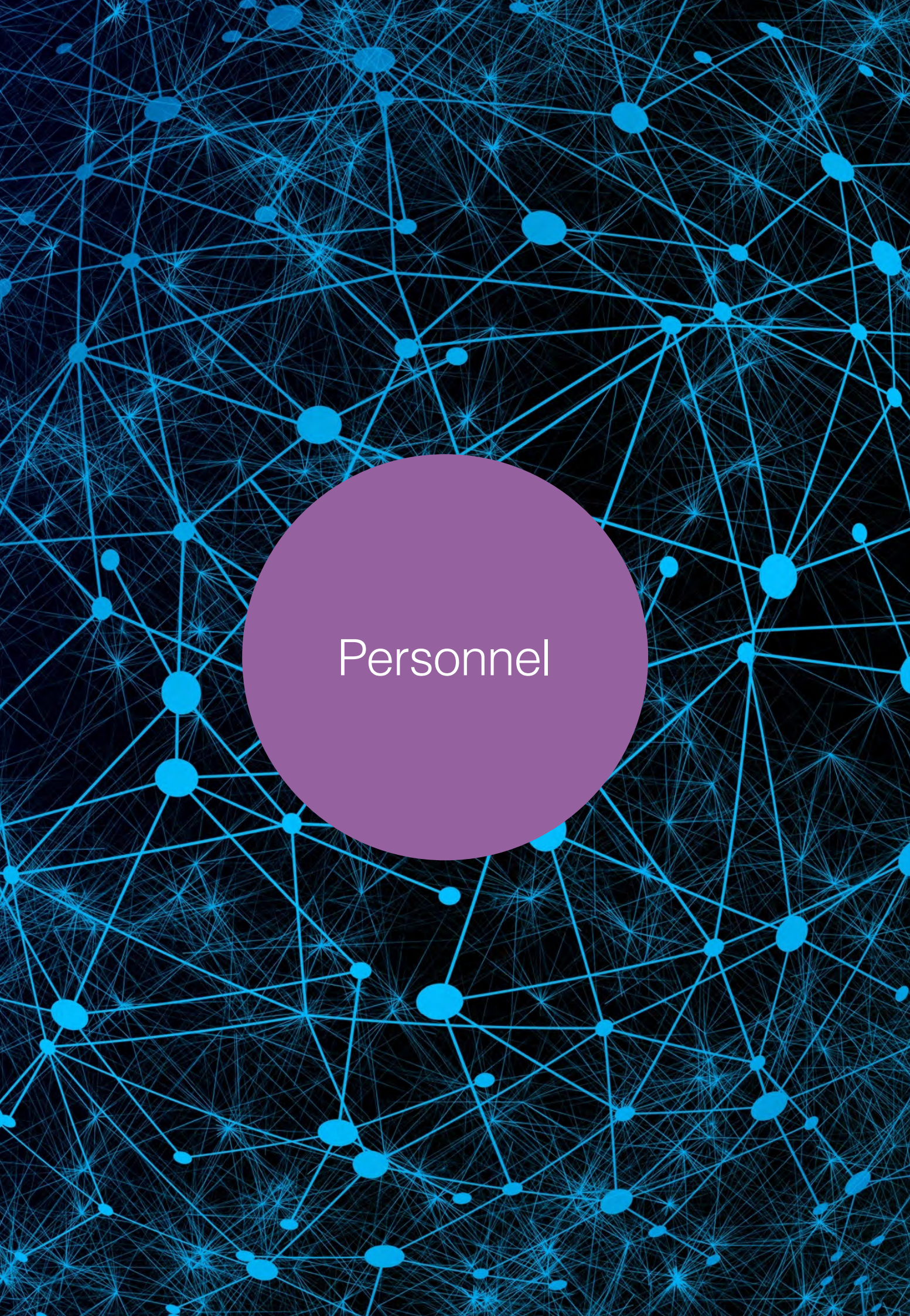
The annual conference for the Australian Chapter of OHBM aims to unite and invigorate the neuroimaging community in Australia. This year, the conference was hosted by the University of Newcastle at the Hunter Medical Research Institute and brought together postgraduate students, early career researchers, and established academics.

The meeting featured international keynote speaker Sarah Garfinkel (UK) and two Australian keynote speakers, Alex Fornito (Monash University) and Amy Brodtmann (the Florey Institute of Neuroscience and Mental Health) as well as other speakers, poster presentations and a lively debate considering the pros and cons of models versus machine learning. To encourage personal development and networking opportunities, the meeting also incorporated an early career researcher workshop, dinner, networking barbeque and early career researcher breakfast.

At the meeting, OHBM Australia's current Chair, Jason Mattingley (University of Queensland), launched the Chapter's new website (<https://ohbmaustralia.wordpress.com/>).

Funding from the Brain Function CoE was used to provide travel bursaries for 26 early career researchers.





# PERSONNEL

CIs • management/administration • coordinators • investigators • fellows • scholars • affiliates

## Chief Investigators

Click on profile picture to read more about each of our chief investigators



Gary Egan  
Director  
Monash University



Marcello Rosa  
Deputy Director  
Monash University



Jason Mattingley  
Associate Director  
University of Queensland



Michael Ibbotson  
Chief Investigator  
University of Melbourne



Arthur Lowery  
Chief Investigator  
Monash University



Paul Martin  
Chief Investigator  
University of Sydney



Pankaj Sah  
Chief Investigator  
University of Queensland



Stan Skafidas  
Chief Investigator  
University of Melbourne



Greg Stuart  
Chief Investigator  
Australian National University



Ehsan Arabzadeh  
Chief Investigator  
Australian National University



Marta Garrido  
Chief Investigator  
University of Melbourne



Ulrike Grünert  
Chief Investigator  
University of Sydney



George Paxinos  
Chief Investigator  
University of New South Wales



Steve Petrou  
Chief Investigator  
University of Melbourne



Peter Robinson  
Chief Investigator  
University of Sydney



# PERSONNEL

CIs • management/administration • coordinators • investigators • fellows • scholars • affiliates

## Management and Administration

- Glenn Papworth, Chief Operating Officer, Monash University
- Jessica Despard, Senior Officer (*maternity leave*), Monash University
- Katja Gutwein, Senior Officer (*maternity leave replacement*), Monash University
- Merrin Morrison, Communications Officer, Monash University
- Masha Perry, Senior Administration Officer, Monash University
- Hatice Sarac, Senior Administration Officer, Monash University
- Teri Furlong, Node Administrator, University of Melbourne
- Cindy Guy, Node Administrator, University of Sydney
- Roxanne Jemison, Node Administrator, University of Queensland
- Tenille Ryan, Node Administrator, University of Melbourne
- Danielle Ursino, Node Administrator, Australian National University

## Program Coordinators

- Adrian Carter, Neuroethics Coordinator, Monash University
- Lindy Fitzgerald, Chair, Gender, Equity & Diversity Committee, University of Western Australia
- Pulin Gong, Neuroinformatics and Computational Resources Coordinator, University of Sydney
- Wojtek Goscinski, Neuroinformatics and Computational Resources Coordinator, Monash University

## Partner Investigators and Organisations

- Michael Breakspear, QIMR Berghofer Medical Research Institute
- Matthew Diamond, International School for Advanced Studies, Italy
- Sean Hill, International Neuroinformatics Coordinating Facility (INCF), Sweden
- Viktor Jirsa, Aix-Marseille University, France
- G. Allan Johnson, Duke University, USA
- David Leopold, NIH: National Institute of Mental Health, USA
- Troy Margrie, The Francis Crick Institute, UK
- Henry Markram, Blue Brain Project, Switzerland
- Partha Mitra, Cold Spring Harbor Laboratory, USA
- Tony Movshon, New York University, USA
- Keiji Tanaka, Riken Brain Institute, Japan
- Jonathan Victor, Weill Cornell Medicine, USA

## Associate Investigators

- Derek Arnold, University of Queensland
- Sofia Bakola, Monash University
- John Bekkers, Australian National University
- Anthony Burkitt, University of Melbourne
- Vincent Daria, Australian National University
- Paul Dux, University of Queensland
- Alex Fornito, Monash University
- Geoff Goodhill, University of Queensland
- Ted Maddess, Australian National University
- Farshad Mansouri, Monash University
- Nic Price, Monash University
- Ramesh Rajan, Monash University
- Fabio Ramos, University of Sydney
- Olaf Sporns, Indiana University, USA
- Nao Tsuchiya, Monash University
- Trichur Vidyasagar, University of Melbourne
- Charles Watson, Curtin University



### Professor Pankaj Sah Chief Investigator, University of Queensland

Professor Pankaj Sah is group leader and Director of the Queensland Brain Institute (QBI) at The University of Queensland (UQ). He is renowned for his work in understanding the neural circuitry of the amygdala, an area of the brain that plays a central role in emotional processing and its impact on learning and memory formation.

His laboratory uses a combination of molecular tools, electrophysiology, anatomical reconstruction, calcium imaging and behavioural studies to understand connections within and with the amygdala and their impact on fear related learning. These studies are unravelling the basic neural circuits that underpin one form of simple learning in the mammalian nervous system. His laboratory also works with patients undergoing electrode implantation for deep brain stimulation, which is used to treat a variety of disorders such as Parkinson's disease, Tourette's syndrome and Essential Tremor.

Professor Sah trained in medicine at the University of New South Wales and, after completing his internship, gained a PhD from the Australian National University. Following postdoctoral work at The University of California, San Francisco, and UQ, he established his own laboratory at the University of Newcastle in 1994. He then joined the John Curtin School of Medical Research at the Australian National University as a group leader in 1997. He was recruited to QBI as a founding member in 2003, and has been Director since July 2015. Professor Sah has published over 110 papers in international peer-reviewed journals. He is also the Editor-in-Chief of the Nature Partner Journal npj Science of Learning, the first journal to bring together the findings of neuroscientists, psychologists, and education researchers to understand how the brain learns.



### Professor Charles Watson Associate Investigator, Curtin University

Professor Charles Watson AM, Senior Research Fellow, Neuroscience Australia, received a medical degree and a DSc from The University of Sydney and holds a specialist fellowship in public health medicine. He has worked on brain atlases with George Paxinos for over 40 years. Their best known publication ('The Rat Brain in Stereotaxic Coordinates') is now in its 7th edition and has been cited over 80,000 times. Charles' main current research interests are in spinal cord anatomy and developmental gene expression in the brain. As well as his position at Neura, he holds professorial appointments at the University of New South Wales, Curtin University, and the University of Queensland.

Charles received the Distinguished Achievement Award from the Australasian Neuroscience Society in 2018. He is an accomplished teacher and is chief examiner in neuroanatomy and neurology for the Australasian Brain Bee Challenge.



# PERSONNEL

CIs • management/administration • coordinators • investigators • fellows • scholars • affiliates

## Centre Fellows

- Massoud Aghili Yajadda, University of Sydney
- Tahereh Babaie-Janvier, University of Sydney
- Ilvana Dzafic, University of Queensland
- Calvin Eiber, University of Sydney
- Timothy Feleppa, Monash University
- Ben Fulcher, University of Sydney
- Teri Furlong, University of New South Wales
- Natasha Gabay, University of Sydney
- Demi Gao, University of Sydney
- Saba Gharaei, Australian National University
- James Henderson, University of Sydney
- Sharna Jamadar, Monash University
- Tim Karle, University of Melbourne
- Steve Kassem, University of New South Wales
- Ehsan Kheradpezhough, Australian National University
- Stuart Knock, University of Sydney
- Sammy Lee, University of Sydney
- Rania Masri, University of Sydney
- Roger Marek, University of Queensland
- Hamish Meffin, University of Melbourne
- Anand Mohan, Monash University
- Babak Nasr, University of Melbourne
- David Painter, University of Queensland
- Alexander Pietersen, University of Sydney
- Svetlana Postnova, University of Sydney
- Matthew Tang, University of Queensland
- Phillip Ward, Monash University
- Massoud Yajadda, University of Sydney
- Dongping Yang, University of Sydney
- Natalie Zeater, University of Sydney
- Zhijian Cai, Monash University
- Guozhang Chen, University of Sydney
- India Cowie-Kent, Monash University
- Guthrie Dyce, Australian National University
- Daniel Fehring, Monash University
- Mariya Ferdousi, University of Sydney
- Kate Gillespie-Jones, Monash University
- Richard Gillies, University of Melbourne
- Clare Harris, University of Queensland
- Suraj Honnuraiah, Australian National University
- Pippa Iva, Monash University
- Young Jun (Jason) Jung, University of Melbourne
- Shivam Kalhan, University of Melbourne
- Thomas Lacy, University of Sydney
- Yuxi Liu, University of Sydney
- Xiaochen Liu, University of Sydney
- Xian Long, University of Sydney
- Rania Masri, University of Sydney
- Kamrun Mukta, University of Sydney
- Eli Muller, University of Sydney
- Brandon Munn, University of Sydney
- Daniel Naomenko, University of Sydney
- Suba Nasir-Ahmad, University of Sydney
- Gratia Nguyen, University of Sydney
- Shencong Ni, University of Sydney
- Brian Oakley, Monash University
- Edwina Orchard, Monash University
- Yang Qi, University of Sydney
- Kevin Qu, University of Sydney
- Taylor Singh, Australian National University
- Christodoulos Skilros, University of New South Wales
- Cong Wang, University of Queensland
- Asem Wardak, University of Sydney
- Chalini Wijetunge, University of Melbourne

## Centre Scholars

- Sahand Assadzadeh, University of Sydney
- Elissa Belluccini, University of Sydney
- Tessa Borloo, University of Queensland
- Alexander Bryson, University of Melbourne



**Dr Teri Furlong**  
**Senior Research Fellow**  
**University of New South Wales**

Teri received her PhD from the University of New South Wales, and then furthered her expertise in behavioural neuroscience in Sydney (The University of Sydney and the University of NSW), as well as the University of Utah, USA.

Teri is currently a Senior Research Fellow working with Professor George Paxinos and Professor Charles Watson on creating brain atlases. These brain atlases are like road maps which aid researchers and clinicians in navigating the brain. Last year their Brain Function CoE atlas of the Human Brainstem was published in book form. This book has just been nominated for a 2020 PROSE award by the Association of American Publishers for excellence in biological and life science. Further, this book received a lot of media attention with more than 600 articles published across 50 countries due to the discovery of a new brain region. They named this brain region the endorestiform nucleus due to its location inside the restiform body in the brain. Now that the endorestiform nucleus has been discovered, scientists need to determine its precise function, which is likely to be in motor co-ordination given its location in the brain.



**Dr Matthew Tang**  
**Senior Research Fellow, University of Queensland**

Matt completed his PhD in vision science at the University of Western Australia under the supervision of Professor David Badcock in 2016. He then joined the ARC Brain Function CoE as a postdoctoral fellow with Professor Jason Mattingley at the University of Queensland.

Here he developed analytic and experimental techniques to determine how attention and prediction affect the brain’s representation of visual information. During this time, he and Professor Mattingley established a collaboration with Professor Ehsan Arabzadeh from the Australian National University to develop sensory decision tasks that humans and rodents could complete where attention and prediction are manipulated in the same manner while brain activity is recorded using EEG/neuroimaging in humans and single cell electrophysiology/imaging in mice. This work led to a joint NHMRC project grant which allowed Matt to make a recent move to the Australian National University as Research Fellow to learn animal neurophysiology from Professor Arabzadeh.

Matt’s collaboration with Professor Arabzadeh has led to the implementation of a recording system using Neuropixel electrodes to simultaneously record activity across multiple areas of the mouse brain. They are planning experiments examining how prediction and attention affects coordinated activity across the visual processing hierarchy.



# PERSONNEL

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## Dan Fehring PhD Scholar, Monash University

Dan is a PhD student who, under the supervision of Professor Farshad Mansouri and Professor Marcello Rosa at Monash University, is due to submit his thesis for examination in early 2020. His PhD focused on how decision-making processes can be altered by environmental stimuli, such as visual images or music, or through the electrical stimulation of cortical brain areas. Moreover, he also examined the neurobiological basis of these cognitive processes. This research has led to numerous publications, including articles published in Cerebral Cortex and Nature: Scientific Reports.

Dan is currently working on a series of collaborative projects with PI Keiji Tanaka and AI Farshad Mansouri at RIKEN Center for Brain Science in Japan. These projects aim to elucidate the neuronal contributions of certain brain areas which support decision-making processes. An area of particular interest is the insular cortex, which although has been implicated in various cognitive functions, its neuronal contributions remain unknown.



## Winnie Orchard PhD Scholar, Monash University

Winnie is a PhD student under the supervision of Dr Sharna Jamadar at Monash University. With a background in psychology and physiology, Winnie’s research focuses on the parental brain; how pregnancy and parenthood change the human brain. Using MRI, Winnie investigates the structure and function of the parental brain, and implications for maternal cognition and mental health across the lifespan. Winnie is currently recruiting participants for the NAPPY study (Neural Adaptations of the PostPartum Year), which won first prize in the Centre’s three-minute fellowship competition in 2019.

Winnie is committed to service and advocacy in the scientific and general communities, acting as the moderator for the Australasian Women in Neuroscience Society (AWINS), and will serve as the Victorian representative for the Brain Function CoE Early Career Researcher committee for 2020. Winnie also creates social media content to communicate her findings and the latest literature back to the community.



## Shivam Kalhan PhD Scholar, University of Melbourne

Shivam is a PhD student under the supervision of Associate Professor Marta Garrido at the University of Melbourne. With a background in neuroscience, Shivam’s research focuses on the neural and computational mechanisms driving decision-making deficits in those with drug addictions. To do this, he utilises fMRI imaging, computational modelling and behavioural tasks to better understand the specific brain processes and computations that go awry and how they may be ameliorated.

From his undergraduate work, Shivam has published a paper in Scientific Reports investigating the role of anterior cingulate cortex and ventral tegmental area in adaptive decision-making. He has also recently received a grant from the University of Melbourne, School of Psychology and another grant from the Brain Function CoE for coming second place in the three-minute fellowship competition. He will apply these funds to use 7T-fMRI and investigate the role of belief modulation and cravings in reducing the impulsive decision-making deficits in nicotine smokers.



## Angela Renton PhD Scholar, University of Queensland

Angela Renton is a PhD student supervised by Professor Jason Mattingley. Her PhD, titled ‘Neurofeedback Investigations of Perceptual Processes’, focusses on developing real-time signal processing methods for EEG in order to investigate and boost the neural signals associated with visual selective attention. Early in her PhD, Angela’s team’s research was funded in the Brain Function CoE Early Career Researcher Pitch competition, allowing her to extend her skillset through a novel interdisciplinary collaboration. Angela has shared her research by publishing two first author manuscripts in high impact journals and contributing to ‘*The Conversation*’. Last year, Angela was accepted to attend the prestigious CIFAR Machine Learning Summer School in Alberta, Canada with a travel award. She was also awarded travel grants from both the Brain Function CoE and Australasian

Cognitive Neuroscience Society to attend national conferences. Angela regularly volunteers for science outreach programs such as Wonder of Science, Pint of Science, and the Australian Brain Bee Challenge.

# PERSONNEL

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## Honours Students

- Lachlan Coulthard, University of Melbourne
- Jess Hamley, University of Sydney
- Shuang Jiang, Australian National University
- Jack Kelso-Ribbe, University of Queensland
- Emily McCann, University of Queensland
- Mariah Mwipatayi, University of Melbourne
- Vinali Naido, Monash University
- Anton Newgreen, University of Melbourne
- Lachlan Owensby, Australian National University
- Zoe Stawyskyj, University of Sydney
- Anlai Wei, University of Sydney

## Professional Staff

- Shi Bai, Monash University
- Arzu Demir, University of Sydney
- Brendon Harris, University of Sydney
- Mcloskey Keira, University of New South Wales
- Mario Novelli, University of Sydney
- Ramadan Tanya, University of New South Wales

## Affiliate Professional Staff

- David Lloyd, University of Queensland
- Petra Sedlak, University of Queensland
- Cecilia Cranfield, Monash University
- Katrina Worthy, Monash University
- Cristina Ciornei, Monash University
- Daria Malmanova, Monash University
- Kirsty Watkins, Monash University
- Anthony Harris, University College London
- Imogen Stead, University of Queensland
- Li Xu, University of Queensland
- Rebecca Bhola, Monash University
- Kelly O’Sullivan, Monash University
- Jeremy Taylor, University of Queensland

## Affiliate Academics

- Oliver Baumann, Bond University
- Gursharan Chana, University of Melbourne
- Răzvan Gămănuț, Monash University
- David Garret, University of Melbourne
- David Grayden, University of Melbourne
- Wendy Imlach, Monash University
- Tania Kameneva, University of Melbourne
- Leo Lui, Monash University
- Adam Morris, Monash University
- Steven Prawer, University of Melbourne
- David Reser, Monash University
- Margreet Ridder, University of Queensland
- Tatsuo Sato, Monash University
- Mark Schira, University of Wollongong
- Daisuke Shimaoka, Monash University
- Peter Stratton, University of Queensland
- Tahereh Tekieh, University of Sydney
- Fabrice Turpin, University of Queensland
- Francois Windels, University of Queensland
- Yan Wong, Monash University
- Hsin-Hao Yu, Monash University



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## Affiliate Fellows

- Ali Almasi, University of Melbourne
- Nafiseh Atapour, Monash University
- Christopher Nolan, University of Queensland
- Pawan Bista, Monash University
- Claire Bradley, University of Queensland
- Tristan Chaplin, Monash University
- Shaun Cloherty, Monash University
- Kristen Farrell, Australian National University
- Hannah Filmer, University of Queensland
- Konstantinos Hadjidimitrakis, Monash University
- Maureen Hagan, Monash University
- Will Harrison, University of Queensland
- James Henderson, University of Sydney
- Helena Huang, Australian National University
- Cliff Kerr, University of Sydney
- Marcin Kielar, University of Queensland
- Melissa Larsen, University of Queensland
- Conrad Lee, Australian National University
- Delphine Levy-Bencheton, University of Queensland
- Snezana Maljevic, University of Melbourne
- Jessica McFadyen, University of Queensland
- Sam Merlin, University of Western Sydney
- John Morris, University of Queensland
- Eli Muller, University of Sydney
- Brandon Munn, University of Sydney
- Madhusoothanan Bhagavathi Perumal, University of Queensland
- Lei Qian, University of Queensland
- Dragan Rangelov, University of Queensland
- Kay Richards, University of Melbourne
- Sullivan Robert, University of Queensland
- Somwrita Sarkar, University of Sydney
- Shi (Scott) Sun, University of Melbourne
- Yajie Sun, University of Queensland

- Angelo Tedoldi, University of Queensland
- Wei Tong, University of Melbourne
- Molis Yunzab, University of Melbourne
- Elizabeth Zavitz, Monash University
- Iris Zhu, Monash University

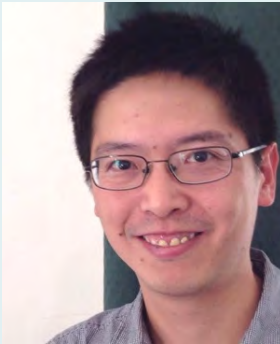
## Affiliate Scholars

- Talina Bayeleva, University of Queensland
- Nicholas Bland, University of Queensland
- Jonathan Chan, Monash University
- Yadeesha Deerasooriya, University of Melbourne
- Amu Faiz, University of Queensland
- Masoud Ghodrati, Monash University
- Basem Hassan, University of Melbourne
- Linghan Jia, University of Melbourne
- Liliana Laskaris, University of Melbourne
- Ting Ting Lee, University of Melbourne
- Tianzhi Li, University of Melbourne
- You Liang, University of Melbourne
- Caixia Lin, University of Queensland
- Jamie McFadyen, Monash University
- Morgan McIntyre, University of Queensland
- Samra Naz, University of Queensland
- Roshini Randeniya, University of Queensland
- Angela Renton, University of Queensland
- Declan Rowley, Monash University
- Najmeh Sajedianfard, University of Sydney
- Blake Saurels, University of Queensland
- Cooper Smout, University of Queensland
- Shi (Scott) Sun, University of Melbourne
- Susan Travis, University of Queensland
- Jason Yong, University of Melbourne
- Yang Yu, University of Melbourne

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## Alumni



### Dr Hsin-Hao Yu Research Scientist, IBM Research Australia

Prior to moving to industry, Hsin-Hao was a research fellow at the Department of Physiology, Monash University. There he used electrophysiology, imaging, and computational modelling to study how the visual information is processed in the brain.

In the middle of 2018, he made a career move to work for IBM Research Australia as a research scientist. At IBM, he works with a multidisciplinary team of computer scientists, engineers and clinicians to develop artificial intelligence algorithms for healthcare-related problems. Although he had no prior experience in artificial intelligence, he found out that he could help advance the goals of his team, because developing AI models, especially in the biomedical domain, depends greatly on domain knowledge.

In his experience, the skills that university scientists have are highly transferable to industry. The ability to digest a wide range of highly specialised knowledge, to think critically about them, and to extract relevant insights from them is a skill that has to been learned and practiced. So are the abilities to work with diverse collaborators, and to communicate complex ideas efficiently. There is another valuable skill that he believes is not commonly recognised: the ability to make progress for ambitious goals, in the face of high uncertainty, high risk and high competition. He believes that the university is an excellent place to train people with these extraordinary skills, and it is in the best interest of industry to take advantage of academic talents.



### Dr Phillip Ward Research and Development Data Scientist, National Australia Bank

Phillip completed his PhD in Neuroimaging at Monash University in 2017 and went on to complete three years of postdoctoral research with Professor Gary Egan. During this time, he developed numerous MRI analysis techniques, an atlas of the cerebral veins, mapped iron levels in neurological disease, and worked on models of simultaneous neuronal and metabolic activity in the brain. In 2018, he was named a VESKI Victoria Fellow, and was awarded a NHMRC Investigator Grant in 2019. He was elected Junior Fellow of the International Society for Magnetic Resonance in Medicine in 2020.

In late 2019, Phillip took a position at the National Australia Bank (NAB) as a Research and Development Data Scientist, working within the advanced analytics team on machine learning and data privacy. He maintains close ties with academia, continuing to publish research and collaborate as a casual researcher.

His time at NAB has been spent looking at mathematical guarantees of information disclosure in modelling, and robust methods to generalise models from samples to populations. He has found his training and experience in handling diverse datasets and applying bespoke statistics highly valuable in industry. The team he is based within has several members with PhDs in diverse fields from database algorithms to astrophysics. The common thread among them is the independence, curiosity, and diligence that completing a PhD brings. He has found industry has a strong desire for post-docs from diverse backgrounds but struggles to find them.



### Dr Jessica McFadyen Postdoctoral Research Fellow, University College London

Jessica is a postdoctoral research fellow at University College London, working with Prof Ray Dolan in the Max Planck UCL Centre for Computational Psychiatry and Ageing Research. After graduating with first-class honours from a Bachelor of Psychological Science, Jessica completed a PhD under the supervision of A/ Prof Marta Garrido and Prof Jason Mattingley at the Queensland Brain Institute. Here, Jessica explored the anatomy and function of amygdala pathways that transmit visual information. Her work has granted insight into how the brain rapidly and unconsciously responds to emotional stimuli.

After being awarded her PhD, Jessica relocated to London to work with Prof Ray Dolan. Here, Jessica is currently conducting research on how the brain encodes the series of events that lead to reward and loss. She uses a combination of magnetoencephalography and computational modelling to relate neural behaviour to anxious pathology.



# COLLABORATION NETWORK

● Roll over location markers for full lists





# KEY PERFORMANCE INDICATORS

| Performance KPIs  | Target | Actual | %    |
|---|--------|--------|------|
| <b>Research Outputs</b> – with Centre acknowledgement or inclusion as an author affiliation   |        |        |      |
| Journal articles  | 40     | 93     | 233% |
| Books   | 0      | 2      | 200% |
| Book chapters   | 0      | 2      | 200% |
| Conference papers   | 3      | 2      | 66%  |
| AV recordings   | 0      | 5      | 500% |
| <b>Publication Quality</b> – with Centre acknowledgement or inclusion as an author affiliation  |        |        |      |
| Citations (cumulative)  | 600    | 1,456  | 242% |
| Average impact factor   | 4      | 4.842  | 121% |
| Average web views per article   | 1,000  | 1,659  | 166% |
| Average Altmetric score   | 10     | 12.46  | 125% |
| <b>Number of training courses offered by Centre</b>   |        |        |      |
| Professional development training (including media training, pitch training, research translation, journal writing – 2 x online & 2 x face-to-face) | 4      | 6      | 150% |
| <i>(All sessions were offered face-to-face, in place of online sessions)</i>  |        |        |      |
| <b>Number of workshops/conferences held/offered by the Centre</b>   |        |        |      |
| National science meeting  | 1      | 2      | 200% |
| International meeting/ workshop   | 1      | 1      | 100% |
| ECR workshop  | 1      | 2      | 200% |
| <b>Additional Researchers</b>   |        |        |      |
| Post-doctoral researchers   | 25     | 26     | 104% |
| Honours students  | 8      | 11     | 138% |
| PhD students  | 25     | 32     | 128% |
| Masters students  | 0      | 4      | 400% |
| Affiliate Investigators <i>(students and researchers contributing to Centre activities who do not receive Centre funding)</i>                       | 80     | 98     | 123% |
| <b>Number of Postgraduate Completions</b>   | 12     | 18     | 150% |
| <b>Number of Honours Completions</b>  | 8      | 11     | 138% |
| <b>Number of Mentoring Programs offered by Centre</b>   |        |        |      |
| Centre induction program  | 2      | 1      | 50%  |
| Formal mentorship program   | 1      | 1      | 100% |

| Performance KPIs  | Target | Actual | %     |
|---|--------|--------|-------|
| <b>Number of Presentations/ Briefings to the public, government, industry, business, community, end-user or other professional organisation or body</b> | 9      | 18     | 200%  |
| <b>Number of new organisations collaborating with, or involved in the Centre</b>  | 5      | 20     | 400%  |
| <b>Number of Gender, Equity and Diversity Workshops</b>   |        |        |       |
| Face-to Face  | 1      | 1      | 100%  |
| Online  | 1      | 0      | 0%    |
| <i>(All sessions were offered face-to-face, in place of online sessions)</i>  |        |        |       |
| <b>Number of Travel Grants Given to Primary Caregivers</b>  | 4      | 7      | 175%  |
| <b>End User Impact</b>  |        |        |       |
| Public lectures/ events   | 2      | 3      | 150%  |
| Primary & secondary education programs  | 3      | 3      | 100%  |
| Brain Dialogue reach (number of web hits)   | 20,000 | 47,123 | 235%  |
| Media – articles  | 15     | 672    | 4480% |
| Media – invited expert commentary   | 10     | 13     | 130%  |
| <b>National/ International Awards</b>   | 10     | 10     | 100%  |
| <b>Accessibility of Research</b>  |        |        |       |
| Analysis tools available to Centre researchers/ public  | 2      | 7      | 350%  |
| Datasets available to Centre researchers/ public  | 2      | 15     | 750%  |
| <b>Integrative Research</b>   |        |        |       |
| Number of research outputs with authors from more than one group  | 25     | 52     | 208%  |
| Number of interdisciplinary research programs   | 10     | 13     | 130%  |
| <b>International Profile</b>  |        |        |       |
| Number of international visitors  | 10     | 20     | 210%  |
| Number of international presentations   | 25     | 50     | 200%  |
| Number of visits to overseas laboratories   | 16     | 22     | 138%  |



|   | 2014      | 2015      | 2016      | 2017      | 2018      | 2019         |
|---|-----------|-----------|-----------|-----------|-----------|--------------|
|   | \$        | \$        | \$        | \$        | \$        | \$           |
| FUNDS CARRIED FORWARD FROM PREVIOUS YEAR  | -         | 2,741,132 | 3,323,469 | 3,352,518 | 2,748,592 | 2,445,345    |
| Adjustment to carry forward from previous year¹                                       |           |           | 1,976     | 12,984    | 254,354   | -            |
|   |           |           |           |           |           |              |
| INCOME  |           |           |           |           |           |              |
| ARC grant Income  | 2,943,492 | 2,996,205 | 3,047,140 | 3,092,847 | 3,139,239 | 3,198,883.78 |
| Australian National University cash contribution                                      | 111,324   | 111,324   | 111,124   | 111,324   | 111,324   | 111,324      |
| Monash University cash contribution   | 318,434   | 318,434   | 371,625   | 318,795   | 318,795   | 318,795      |
| University of New South Wales cash contribution                                       | -         | 4,445     | 148,002   | 49,334    | 49,334    | 44,890       |
| University of Queensland cash contribution  | 120,390   | 206,800   | 120,390   | 154,370   | 160,520   | 193,962      |
| University of Melbourne cash contribution   | 153,706   | 155,579   | 146,444   | 162,839   | 154,642   | 188,921      |
| University of Sydney cash contribution  | 132,711   | 241,810   | 153,706   | 186,745   | 153,706   | 153,706      |
| Human Brain Project (École polytechnique fédérale de Lausanne-EPFL) cash contribution | -         | 25,000    | -         | -         | -         | -            |
| International Neuroinformatics Coordinating Facility (INCF) cash contribution         | 3,142     | 4,335     | 22,189    | 40,399    | 8,865     | 6,100        |
| Queensland Institute of Medical Research (QIMR) Berghofer cash contribution           | -         | -         | 42,028    | 31,698    | 24,343    | 26,827       |
| Bridge to Mass Challenge  | -         | -         | 225,000   | 25,000    | -         | -            |
| Other income  | 4,955     | 5,700     | 4,130     | 16,000    | 21,139    | 20,769       |
| TOTAL INCOME AND CARRY FORWARD  | 3,788,154 | 6,810,764 | 7,717,223 | 7,554,853 | 7,144,853 | 6,709,522    |
|   |           |           |           |           |           |              |
| EXPENDITURE   |           |           |           |           |           |              |
| Personnel   | 657,528   | 1,892,966 | 2,585,168 | 2,822,705 | 3,152,543 | 2,798,945    |
| Consultants   | 21,287    | 392,266   | 352,984   | 414,111   | 230,976   | 224,117      |
| Scholarships & support  | 28,274    | 115,058   | 37,517    | 112,961   | 136,016   | 94,459       |
| Purchased Equipment   | 35,517    | 132,753   | 147,279   | 259,461   | 39,409    | 59,929       |
| Lease/ Hired Equipment  | 4,163     | 65,607    | 4,583     | 15,903    | 3,437     | 16,470       |
| Maintenance (IT and lab)  | 429       | 78,640    | 2,889     | 77,864    | 14,435    | 13,535       |
| Research Materials / Experiments  | 107,769   | 304,054   | 172,246   | 240,924   | 218,983   | 188,313      |
| Travel and conferences  | 102,608   | 319,067   | 275,872   | 345,879   | 273,676   | 328,058      |
| Sponsorships - scientific workshops & conferences                                     | 4,500     | 10,429    | 11,000    | 20,845    | 20,891    | 23,045       |
| Non-research Initiatives  | 80,217    | 151,752   | 259,710   | 134,553   | 130,257   | 75,714       |
| INCF Subscription   | -         | -         | 339,905   | 311,643   | 332,890   | 83,792       |
| Other Expenditure   | 4,730     | 22,727    | 175,552   | 49,412    | 145,994   | 133,807      |
| TOTAL EXPENDITURE   | 1,047,022 | 3,485,319 | 4,364,705 | 4,806,261 | 4,699,508 | 4,040,187    |
|   |           |           |           |           |           |              |
| BALANCE CARRIED FORWARD TO FUTURE YEARS   | 2,741,132 | 3,325,445 | 3,352,518 | 2,748,592 | 2,445,345 | 2,669,335    |
|   |           |           |           |           |           |              |

| ADMINISTERING AND COLLABORATING ORGANISATION CONTRIBUTIONS | \$        |
|--|-----------|
| Monash University  | 742,725   |
| The Australian National University                         | 272,542   |
| University of New South Wales                              | 102,000   |
| University of Melbourne                                    | 260,661   |
| University of Sydney                                       | 340,015   |
| University of Queensland                                   | 494,082   |
| TOTAL  | 2,212,025 |
|  |           |
| PARTNER ORGANISATION CONTRIBUTIONS                         |           |
| Cold Spring Harbor Laboratory                              | 12,500    |
| Duke University  | 25,000    |
| International School for Advanced Studies                  | 12,500    |
| Karolinska Institute/INCF                                  | 71,566    |
| National Institute for Health and Medical Research         | 12,500    |
| National Institute of Mental Health                        | 12,500    |
| New York University  | 21,703    |
| QIMR   | 108,182   |
| Riken Center for Brain Science                             | 12,500    |
| Weill Cornell Medical College                              | 17,278    |
| TOTAL  | 306,229   |
|  |           |
| TOTAL  | 2,518,254 |



# ADDITIONAL FUNDING

## ARC FUNDING

### ARC Industrial Transformation Research Hubs

Project Title: ARC Research Hub for graphine enabled industry transformation  
IH150100003  
\$2,611,346 (2016-2022)  
Centre Investigator: Stan Skafidas

### ARC Laureate Fellowships

Project Title: The Physical Brain: Emergent, Multiscale, Nonlinear, and Critical Dynamics  
FL140100025  
\$ 2,617,462 (2014-2020)  
Centre Investigator: Peter Robinson

### ARC Linkage Projects

Project Title: Simultaneous to synergistic MR-PET: integrative brain imaging technologies  
LP170100494  
\$673,460 (2018-2021)  
Centre Investigator: Gary Egan

Project Title: Development of far infrared multispectral thermal image sensors  
LP160101475  
\$330,000 (2017-2020)  
Centre Chief Investigator: Stan Skafidas

### ARC LIEF Grants

Project Title: A national magnetic particle imaging facility  
LE 190100084  
\$898,450 (2019-2023)  
Centre Investigator: Gary Egan

### ARC Discovery Projects

Project Title: Linking arterial, brain and cognitive integrity in healthy older adults  
DP200101471  
\$539,000 (2020-2022)  
Centre Investigator: Sharna Jamadar

Project Title: Low-energy electro-photonics: Novel materials, devices and systems  
DP190101576  
\$440,000 (2019-2023)  
Centre Investigator: Arthur Lowery

Project Title: Electrical properties of human dendrites  
DP190103296  
\$490,000 (2019-2023)  
Centre Investigator: Greg Stuart

Project Title: Oscillations as a mechanism for neural communication  
DP200100179  
\$425,000 (2019-2023)  
Centre Investigators: Yan Wong, Nic Price and Maureen Hagan

Project Title: Modelling trajectories of cognitive control in adolescents and young adults  
DP170100756  
\$492,500 (2018-2023)  
Centre Investigator: Sharna Jamadar

Project Title: Neural substrates of paired decision-making training and brain stimulation  
DP180101885  
\$583,271 (2018-2021)  
Centre Investigators: Jason Mattingley and Paul Dux

Project Title: Brain connectome: from synapse, large-scale network to behaviour  
DP180103319  
\$360,517 (2018-2021)  
Centre Investigator: Pankaj Sah

Project Title: Multimodal testing for a fast subcortical route for salient visual stimuli  
DP180104128  
\$414,792 (2018-2020)  
Centre Investigator: Marta Garrido

Project Title: Seeing is believing: Nanophotonic Pixels for Subwavelength imaging on a chip  
DP170100363  
\$452,000 (2017-2021)  
Centre Investigator: Stan Skafidas

Project Title: Neuronal activity underlying efficient sensory processing  
DP170100908  
\$387,500 (2017-2019)  
Centre Investigator: Ehsan Arabzadeh

Project Title: Functional Magnetic resonance imaging: Decoding the palimpsest  
DP170101778  
\$370,500 (2017-2019)  
Centre Investigator: Peter Robinson

Project Title: Hierarchical information processing in the primate visual cortex  
DP170104600  
\$392,000 (2017-2019)  
Centre Investigators: Marcello Rosa, Adam Morris, Hsin-Hao Yu

### ARC DECRA Awards

Project Title: Integration of feedforward and feedback circuits for decision-making  
DE180100344  
\$ 383,551 (2018-2021)  
Centre Investigator: Maureen Hagan

Project Title: Cognitive Compensation in Ageing  
DE150100406  
\$ 375,000 (2015-2019)  
Centre Investigator: Sharna Jamadar

## OTHER

|    |                               |              |
|----|-------------------------------|--------------|
| 1  | NHMRC Program Grant           | \$15,000,000 |
| 2  | NHMRC Development Grants      | \$1,482,414  |
| 4  | NHMRC Fellowships             | \$2,549,748  |
| 28 | NHMRC Project/ Ideas Grants   | \$20,550,062 |
| 5  | Government Grants             | \$8,252,630  |
| 5  | International Grants          | \$5,943,275  |
| 7  | Industry/Philanthropic Grants | \$6,029,222  |
| 9  | Institutional Grants          | \$3,170,950  |





# ACRONYMS

|         |   |
|---------|---|
| AI      | Associate Investigator  |
| ABA     | Australian Brain Alliance   |
| AGM     | Annual General Meeting  |
| ACNS    | Australasian Cognitive Neuroscience Society                           |
| ANS     | Australasian Neuroscience Society                                     |
| ARC     | Australian Research Council   |
| BOLD    | Blood oxygen level dependent  |
| CI      | Chief Investigator  |
| CIBF    | Centre for Integrative Brain Function                                 |
| CoE     | Centre of Excellence  |
| DCM     | Dynamic causal modelling  |
| DECRA   | Discovery Early Career Researcher Award                               |
| DREADDs | Designer receptors exclusively activated by designer drugs            |
| DTI     | Diffusion tensor imaging  |
| ECR     | Early career researcher   |
| EEG     | Electroencephalography  |
| EPFL    | École polytechnique fédérale de Lausanne                              |
| FDG     | Fluorodeoxyglucose  |
| fMRI    | Functional magnetic resonance imaging                                 |
| GED     | Gender, equity and diversity  |
| INCF    | International Neuroinformatics Coordinating Facility                  |
| LGN     | Lateral geniculate nucleus  |
| MASSIVE | Multi-modal Australian ScienceS Imaging and Visualization Environment |
| MEG     | Magnetoencephalography  |
| mPFC    | Medial prefrontal cortex  |
| MRI     | Magnetic resonance imaging  |
| MT      | Middle temporal visual area   |
| NFT     | Neural field theory   |
| PET     | Positron emission tomography  |
| PI      | Partner Investigator  |
| QBI     | Queensland Brain Institute  |
| QIMR    | Queensland Institute of Medical Research                              |
| SISSA   | Scuola Internazionale Superiore di Studi Avanzati                     |
| V1      | Primary visual cortex   |



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