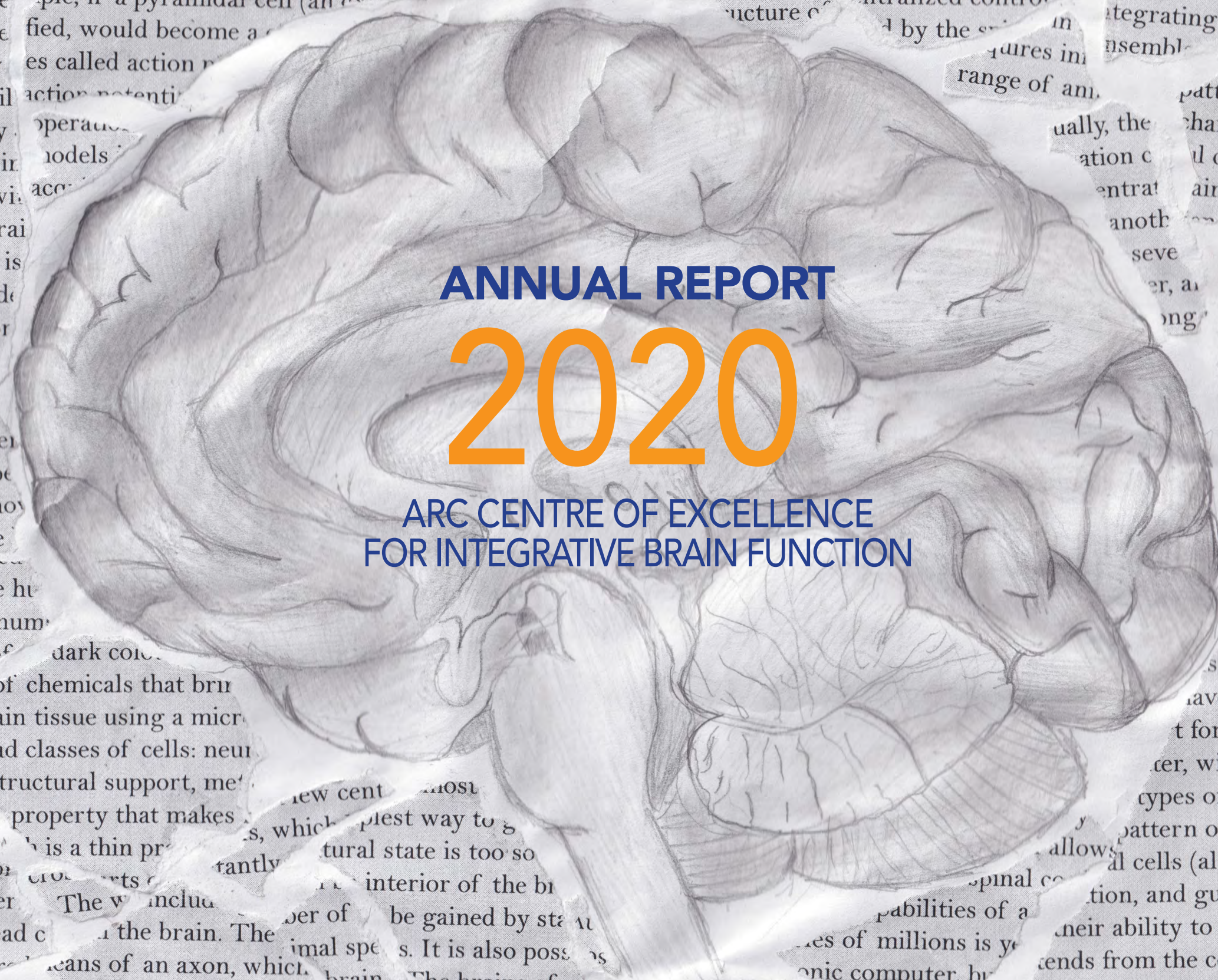


ANNUAL REPORT

2020

ARC CENTRE OF EXCELLENCE  
FOR INTEGRATIVE BRAIN FUNCTION





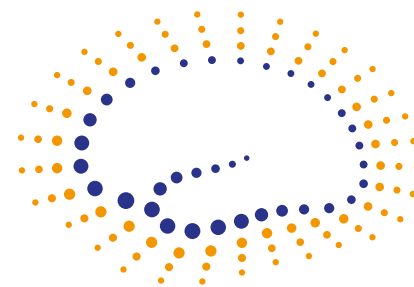
The ARC Centre of Excellence for Integrative Brain Function  
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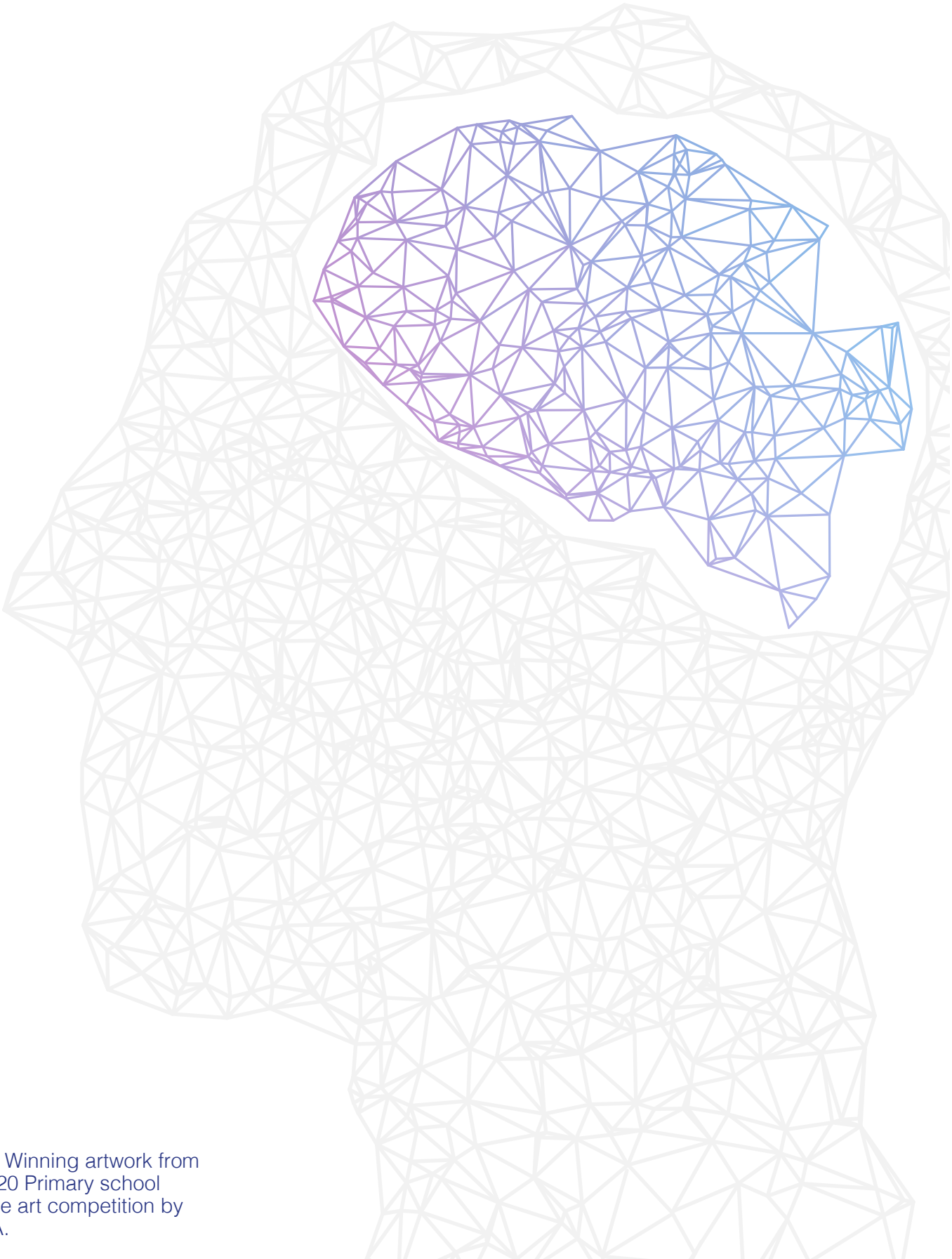
**Australian Research Council**



Australian Research Council  
Centre of Excellence for  
Integrative Brain Function

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Cover: Winning artwork from the 2020 Primary school creative art competition by Jade A.



# Introduction

## 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

1

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



### Networks & Circuits

2

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



### Brain Systems

3

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



### Models, Technology & Techniques

4

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



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.

## 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.



## Director's message



The 2020 Annual Report describes how the Centre of Excellence for Integrative Brain Function continues to undertake outstanding neuroscience research, support and foster the development of the next generation of brain researchers. Throughout a difficult year the Centre members have continued to energetically engage with the wider community to communicate the excitement and importance of understanding how the brain interacts with the world.

This year's report introduces a number of featured research sections which cover the identification of non-classic ganglion cell types in the primate retina, the development of neuroanatomical atlases of the primate cerebrum, and the integration of attentional and decision making neural mechanisms in parallel experiments in human subjects and animal models. These research themes have led to major advances in our understanding of how neural circuits are connected into brain networks, and how these networks are integrated across the scales of the mammalian brain.

We now know how separate pathways that contribute to colour vision and the detection of visual motion also contribute to how we recognise objects and see fine details in the world around us. To better understand spatial vision, Centre researchers Rania Masri, Ulrike Grunert and Paul Martin tracked different cell types involved in these visual processing pathways. They found that the density of the cell network in the midget-parvocellular

pathway precisely matches the level that people need to observe fine visual detail. Mapping the cell density in the retina has helped us to understand this crucial aspect of human visual perception.

The brain processes information by sending electrical signals between cells which change depending on the type of brain cells involved and what function the brain is performing at the time. To understand why fractal-like patterns are important, Centre researchers led by Pulin Gong and Paul Martin analysed cells in the early visual system and detected statistical fingerprints of fractal activity, predominantly in the motion sensitive (MT) cells. Their findings suggest that the fractal quality of spike patterns may enable brain activity to change efficiently in response to irregular threats in the animal's environment, such as the sudden appearance of predators.

Centre researchers led by Marcello Rosa together with collaborators from Australia, Poland, Italy, China and the USA have developed a Marmoset Brain Connectivity Atlas, the first large-scale map of brain connectivity in a non-human primate. Understanding the connections and their complexity in the cerebral cortex is crucial for deciphering brain function. However, mapping this system is an enormous challenge, particularly in complex brains like those of primates. To encourage further research on brain connectivity, the Atlas is freely available to the scientific community and is part of a series of open access resources released by Centre researchers.

A new theoretical framework developed by Centre researcher Farshad Mansouri and colleagues proposes a framework for how abstract rules are formed and used in the primate brain. To perceive our surroundings and help us respond appropriately, our brains use abstract rules and categories to classify objects and events based on past experience. Difficulties in creating these rules and using them properly have been linked to neuropsychological disorders such as autism spectrum disorder and schizophrenia. Rules such as object matching versus non-matching, colour matching versus shape matching, and matching the number of items have been discovered. They proposed that abstract rules emerge from a dynamic, multi-stage process that involve different brain mechanisms and memory, and require the prefrontal cortex to form, store, retrieve and update the rules. Importantly the framework explains the role of the prefrontal cortex in the emergence and implementation of abstract rules for controlling our behaviour.

During rapid processing of images from two target objects we often have no conscious awareness of the second object. Our attention has seemingly blinked and missed it. Centre researchers Matthew Tang and Jason Mattingley developed

a new experimental and imaging method to study the brain during attentional blink. Their results suggest that as soon as we pay attention to something, our brains integrate the visual information that follows even if it is not relevant. This suggests that attentional blink is caused by the brain balancing competing demands using only limited resources and therefore why our brains cannot process many things at once.

Recently published research by Centre researchers Dragan Rangelov and Jason Mattingley has disproved a commonly held belief that attention and decision-making are two independent processes. Most neuroscience research on attention and decision-making has examined these two processes independently and it was unknown whether or how they interact. The study participants were asked to pay attention and make decisions at the same time. The results suggested that paying attention to relevant stimuli and deciding on the appropriate response do occur at the same time showing that attention and decision-making are closely related.

Centre researchers Sharna Jamadar, Phillip Ward and Gary Egan have released a publicly accessible dataset to help researchers investigate and understand network dynamics in the brain. Functional MRI measures oxygenation while FDG-PET measures glucose metabolism in the brain. By making fMRI and PET measurements simultaneously, the neurovascular and metabolic processes underlying brain activity can be examined concurrently. Researchers in the brain imaging community are now able to use this unique dataset to understand the relationship between oxygen and glucose metabolism during dynamic brain function.

During 2020 the Centre's researchers exceeded the ARC targeted scientific outputs with over 70 journal publications, two books and two book chapters, over 2,000 citations to the Centre's research publications, and an average Altmetric score of 6.8. Significantly, Centre researchers exceeded the data accessibility goals with eight analytical tools, eight publicly available datasets, and four scientific audiovisual recordings made publicly available during 2020. The Centre continued to support over 65 postgraduate students and early career researchers. In addition, during 2020, 110 additional researchers were affiliated with the Centre and engaged in collaborative research programs. The Centre also maintained a high number of enrolments of honours students with 13 students completing their projects by the end of the year.

Despite the challenges of 2020, the Centre remained dedicated to upholding our commitment to community engagement through the provision of professional development courses, and media coverage and briefings. Pleasingly there were 27 'In a nutshell'

descriptions of the Centre's research posted on the Brain Dialogue website and more than 600 media articles reporting on the scientific outputs. The Brain Dialogue is the Centre's public engagement platform that publishes 'Discovery' pieces online to highlight research outcomes. The Brain 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.

We are planning how to sustain support for the current educational, public outreach, and community engagement when 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. Our arrangement with the Australasian Neuroscience Society to support the Australian Brain Bee Challenge will extend until the end of 2021. Thank you to Professor Ramesh Rajan for his continued enthusiastic leadership of the Brain Bee Challenge

My sincere thanks once again to Professor Lyn Beazley AO, Chairperson, and to the Centre Advisory Board members for their ongoing commitment to provide oversight and guidance to myself for 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 ongoing support for the Centre's activities under difficult circumstances in 2020.

*Gary F Egan*

*Professor Gary Egan, Centre Director*



## Chair's message



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. It is a big call but it is one that the Centre's researchers relish. Their investigations of brain activity span multiple scales in order to understand better how neural processes associated with attention, prediction and decision-making are integrated and manifest in higher cognition and ultimately behaviour.

Throughout 2020 the Centre continued to meet this significant challenge and continued to make important discoveries that provide insights into the mechanisms of integrative brain function. It is pleasing to see the continued high quality of the scientific publications by the Centre's researchers, and the increasing number of citations confirming the impact of the science as well as media stories that reflect the public interest.

During 2020 the pandemic meant that sadly I was not able to meet with the Centre's early career researchers as I have done in previous years. I have repeatedly been impressed by the passion shown in their research endeavours and in their contributions to the Centre's scientific output, as well as the education and outreach programs. Many of the Centre's young neuroscientists have in previous years 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. This has been

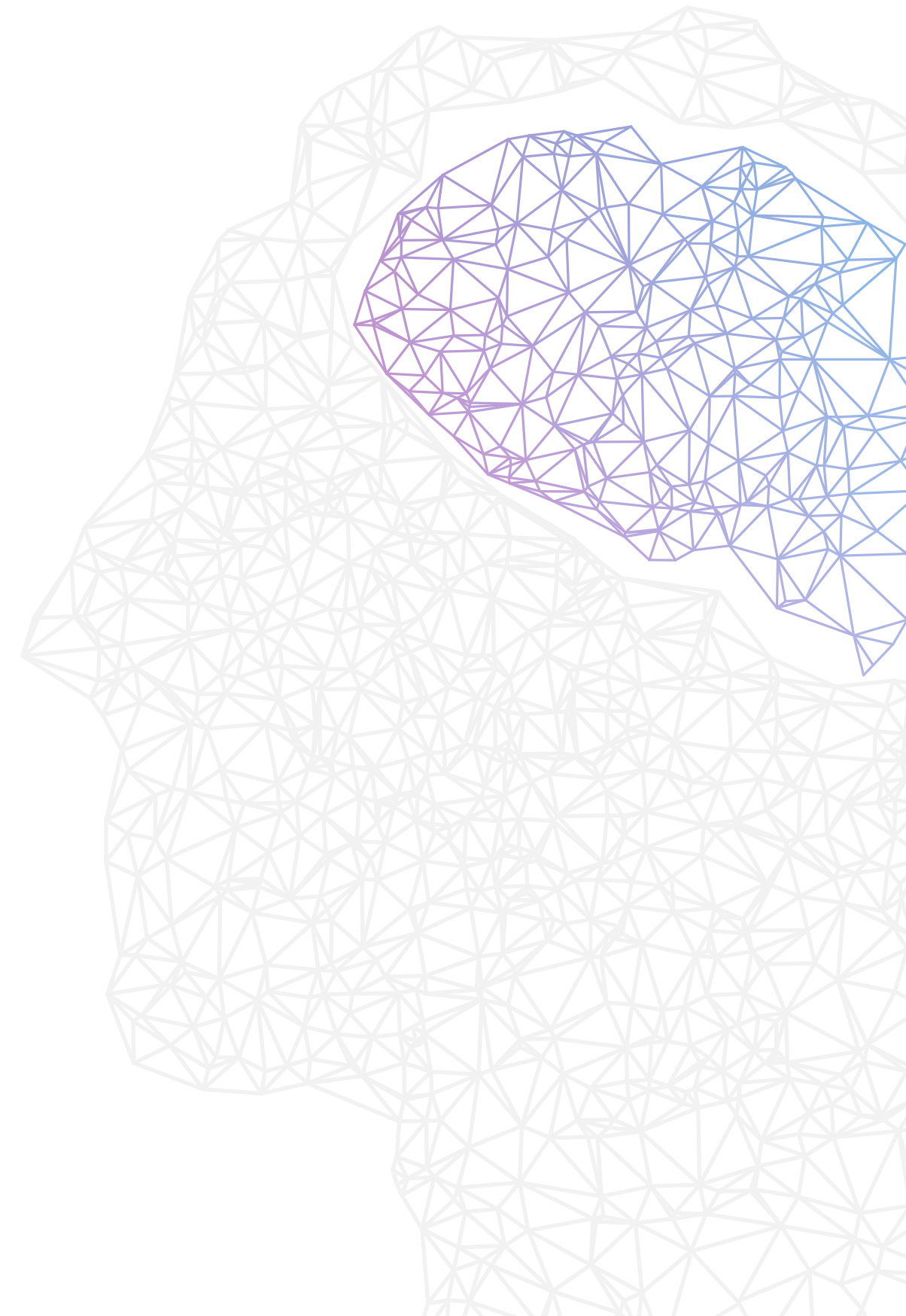
a terrific example of the dedication and commitment by these fledging researchers to promote neuroscience and foster the next generation of brain researchers, and I do hope this will be possible again in 2021.

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. Important initiatives continue to be undertaken both within the Centre and in events organised by the Centre in the research and broader communities. The Gender, Equity and Diversity Committee's work is ensuring the Centre is in the vanguard to promote equity and diversity within and beyond the Australian brain research community. The Centre's leadership team continues to recognise the personal challenges and pressures of being a researcher, especially during the COVID-19 pandemic and in particular the hurdles faced by those researchers for whom English is not their first language.

Whilst my fellow Board members and I were unable to meet face-to-face during 2020, I would nevertheless like to thank them once again for their ongoing commitment to provide governance, support and advice for the Centre. Their combined expertise and experience in scientific research nationally and brain science globally, as well as in broader cultural and financial issues, is an incredible resource for the Centre. I would also like to thank all of the Centre's researchers, staff, higher degree students, post-doctoral research fellows and supporters for their outstanding efforts and wonderful contributions during 2020. Thank you to the Centre's Director, Professor Gary Egan, for his leadership of the Centre together with the tireless work and dedication of the Centre's Chief Operating Officer, Dr Glenn Papworth and the Central Theme administrative team.

I look forward to reconnecting with the Centre members and celebrating their achievements throughout 2021, which will be the final year of Centre funding from the Australian Research Council to advance our understanding of how the brain interacts with the world.

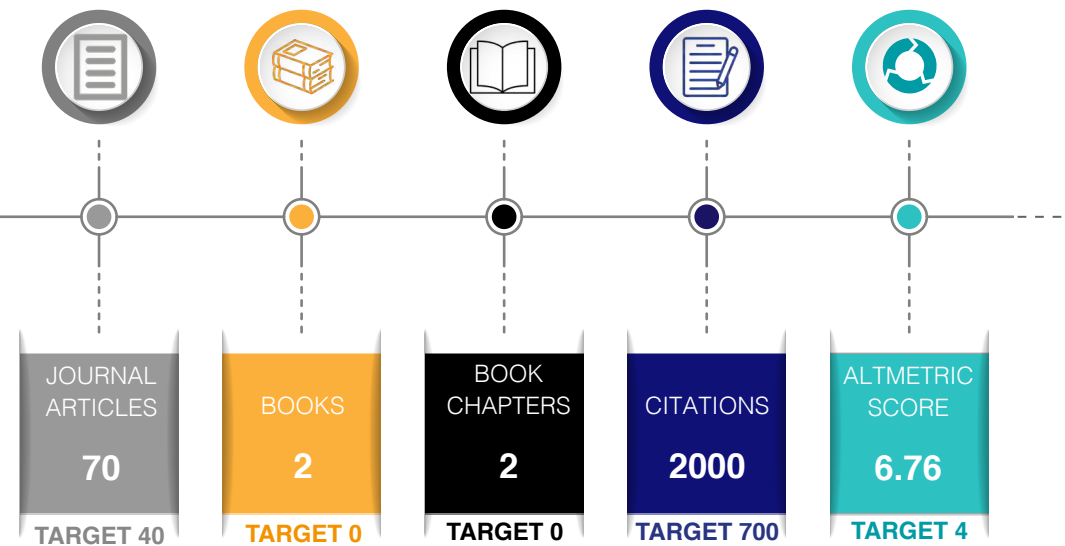
Professor Lyn Beazley AO





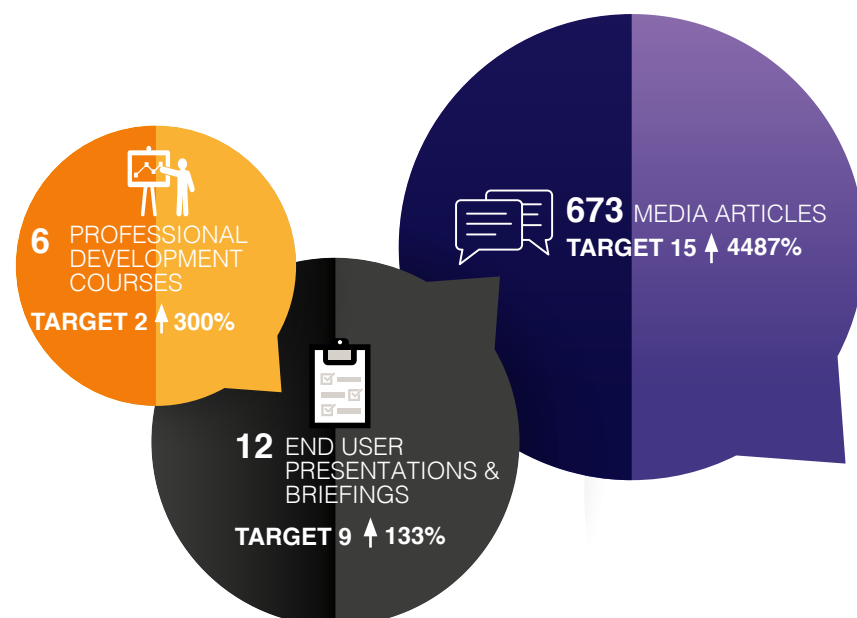
## RESEARCH OUTPUT

Research outputs include all publications with Centre acknowledgement as an author affiliation



## COMMUNITY ENGAGEMENT

Despite the challenges of 2020, the Centre was dedicated to upholding our commitment to community engagement through courses, media coverage and briefings



## DATA ACCESSIBILITY

The Centre exceeded its KPI for data accessibility by 400% in 2020



**8 ANALYSIS TOOLS AVAILABLE TO CENTRE RESEARCHERS / PUBLIC**  
2020 TARGET 2



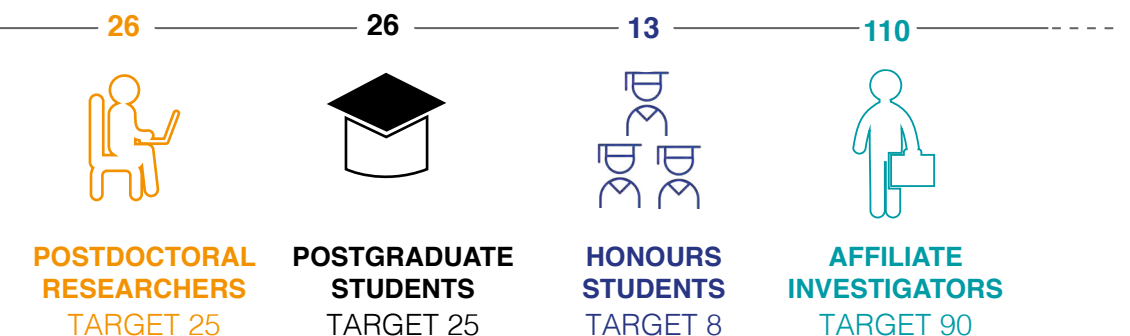
**8 DATASETS AVAILABLE TO CENTRE RESEARCHERS / PUBLIC**  
2020 TARGET 2



**4 PUBLICLY AVAILABLE AV RECORDINGS**  
2020 TARGET 0

## CENTRE PERSONNEL

In 2020 the Centre supported 65 postgraduate students and researchers. 110 additional researchers were affiliated with the Centre, exceeding our target in each case.



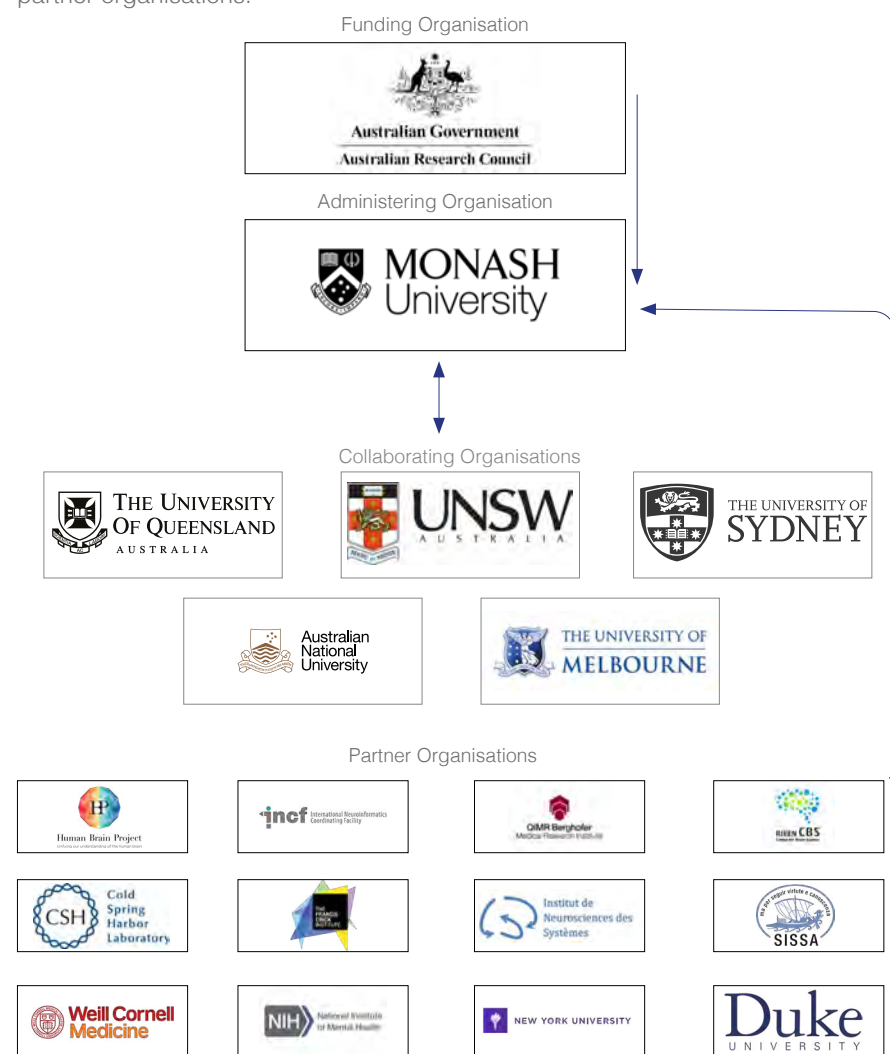
Despite the challenges presented in 2020, the Centre maintained high enrolments of honours students, with 13 students completing their project by the end of the year.



## Organisation and Management

### 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 eleven international partner organisations.



Board meeting photograph from 2019. In 2020 the board maintained its commitment to the Centre via virtual meetings.

### Governance

#### Advisory Board

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, CEO, Allen Brain 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

#### 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 2020, the Executive Committee met monthly and comprised:

- » Prof Gary Egan, Director, Monash University
- » Prof Marcello Rosa, Deputy Director, Monash University
- » Prof Jason Mattingley, Associate and Scientific Director, University of Queensland
- » Prof Pankaj Sah, University of Queensland
- » Prof Greg Stuart, Australian National University
- » Prof Peter Robinson, University of Sydney
- » Prof Michael Ibbotson, University of Melbourne
- » Prof George Paxinos, University of New South Wales
- » Dr Glenn Papworth, Centre Manager, 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 Centre Manager, 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, public education and outreach.



**Program Coordinators and Committee Chairs**

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

- » Neuroethics – A/Prof Adrian Carter, Monash University, Coordinator
- » Gender, Equity and Diversity Committee
  - Prof Melinda Fitzgerald, Curtin University, Chair (until March 2020)
  - Dr Sharna Jamadar, Monash University, Chair (since April 2020)
- » Neuroinformatics
  - Dr Pulin Gong, University of Sydney, Coordinator
  - Dr Wojtek Goscinski, Monash University, Coordinator

**Early Career Researcher Committee**

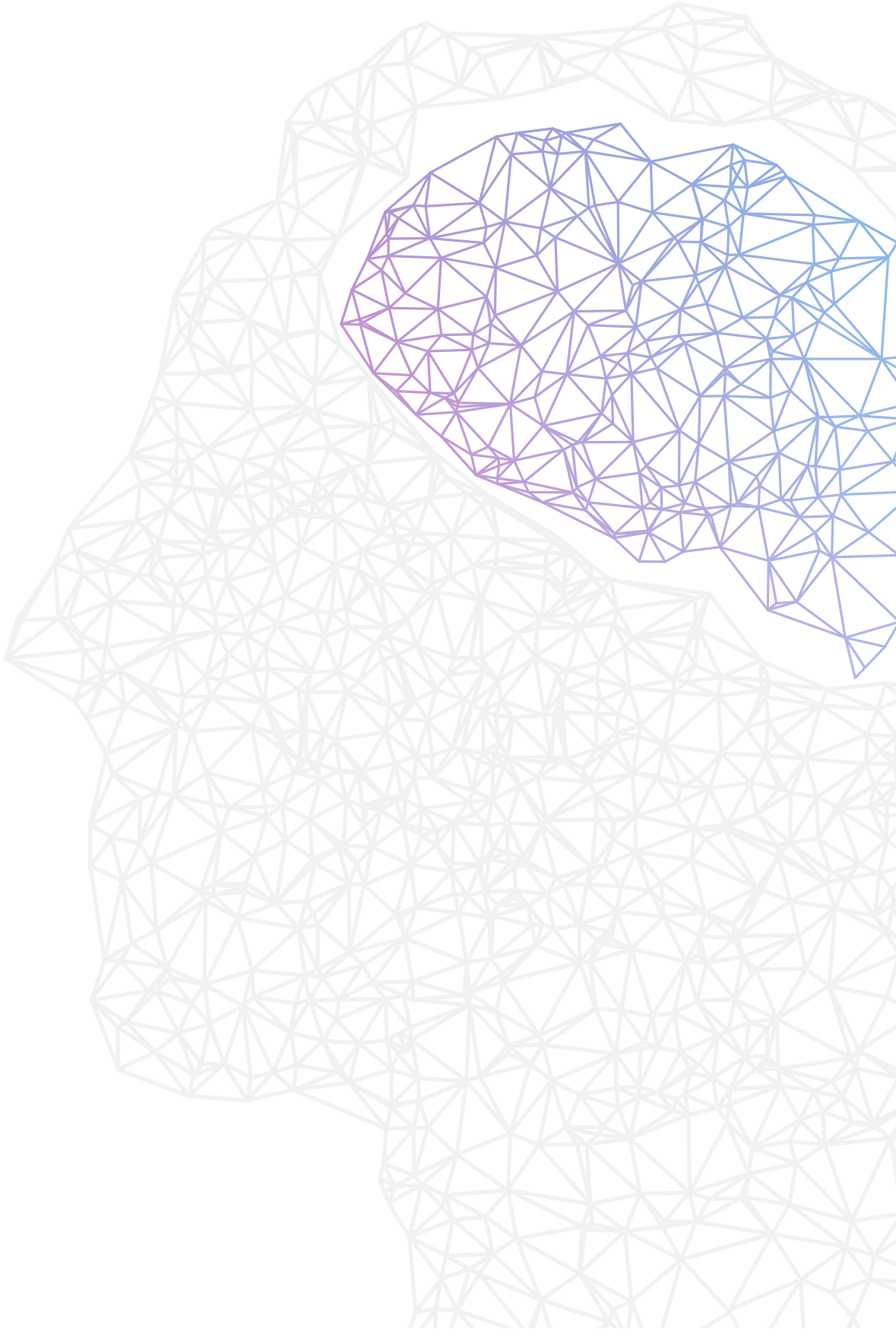
The Centre continues to support Early Career Researchers (ECRs), including PhD students, by offering professional support and development. The ECR committee attends monthly Zoom planning meetings to decide how to manage their Centre allocated budget, in order to provide professional development opportunities for the Centre ECRs.

The 2020 representatives on the ECR committee were:

- » QLD: Anthony Harris, University of Queensland
- » NSW: Kevin Qu, University of Sydney
- » ACT: Dr Robin Broersen, the Australian National University
- » VIC: Winnie Orchard, Monash University



Executive Committee meetings were held virtually in 2020.





# Research

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

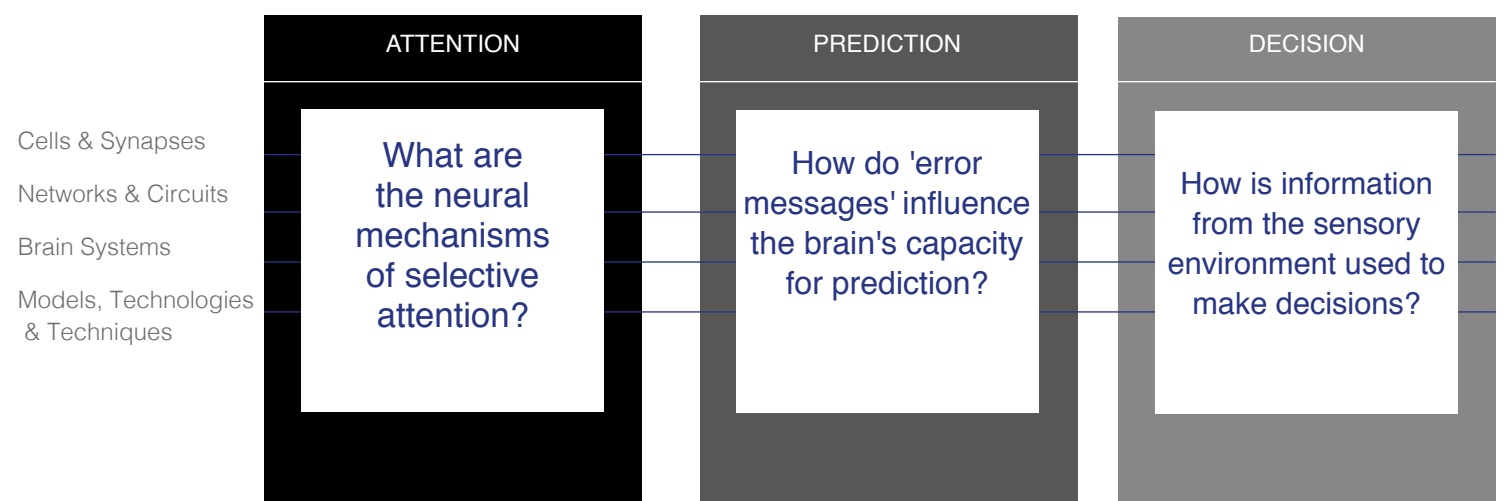
**DECISION** - How is information from the sensory environment used to make decisions?

In 2020 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 2020.

## RESEARCH ACTIVITY DURING COVID-19

The onset of the COVID-19 global pandemic in March 2020 significantly impacted the research program of the Centre. With non-essential staff at all nodes ordered to work from home at multiple points during the year and additional lengthy lockdowns in some cities, many researchers had difficulty accessing the necessary infrastructure to progress their projects as planned in 2020. Centre research programs involving largely human-participant work in particular were adversely affected, with research involving human testing ceasing, and Centre CIs, Fellows, Scholars and research assistants effectively prevented from data collection activities for much of the year. Delays in progress on Centre research projects jeopardised PhD student's abilities to complete their degree projects as planned and post-doctoral researcher's plans for moving to their next career opportunity at the Centre's end.





# Identifying non-classic ganglion cell types in primate retina

Research is shedding light on the purpose of the various ganglion cell types in our visual pathways

Our eyes send different types of messages to our brain to signal the colour, movement and shapes of the objects that we see. This helps us to spot things in our central and peripheral vision – so we can avoid other pedestrians when crossing the road, for example, while also keeping an eye on any fast-approaching cars nearby.

The messages are transmitted by nerve cells in the retina called ganglion cells. Although researchers knew that there are different types of ganglion cells, they were missing information about the number and location of these cells in the retina, and how each type contributes to vision.

The retina of primates contains at least 20 different types of ganglion cells, which are involved with distinct visual connections between the eye and the brain. Few of these ganglion cell types' purpose however are well understood. It is thought that there still more cell types yet to be discovered, potentially projecting to other, brain centres involved in rapid detection of environmental threats and opportunities, and specifically processing information from the peripheral visual field.

Our aim is to develop a greater understanding of these cell types, their structure, their connections within the retina, and their patterns of projection to the brain. We are using molecular markers, intracellular injection and a technique called retrograde tracing, to further our understanding of retinal cell types and their inputs to neuronal circuits in the brain involved in attention.

We discovered that ganglion cells projecting to attention-regulating brain centres are not the expected “conventional” cell types but are part of primitive visual pathways.

We also found that the expression of molecular markers is not conserved across Old World and New World primate species.

Our research has provided further insights into the morphology (structure and arrangement) and distribution of previously poorly understood retinal ganglion cell types.

In our next steps we will further explore the functional role, and the brain connections of low-density retinal ganglion cell types.

*Investigators: Ulrike Grünert, Paul Martin, Marcello Rosa, Sammy Lee, Subha Nasir-Ahmad, Alyssa Baldicano, Kurt Vanstone, Yan Wong, James Bourne, William Kwan, Inaki Mundinano*

How do our eyes send a multitude of messages to our brain simultaneously?



Messages are sent to our brains via **ganglion cells** in the **retina**, giving us both central and peripheral vision

But **where** are they and **how many** do we have?

Also, **which cells** do **what**?



Researchers have examined the **20 different ganglion cells** in primates to discover the **purpose of each of the cell types**.

Molecular markers, intracellular injections and retrograde tracing were used to **understand their role**.



First results show that these cells form part of our **primitive visual pathways**, connected to the **detection of threats**.



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.

**In a nutshell: In the earliest stages of visual processing, the brain detects and processes specific visual features by recognising a simple set of patterns.**

## Visual processing relies on a balance between selectivity and invariance

*Investigators: Michael Ibbotson, Ali Almasi, Hamish Meffin, Yan Wong, Molis Yunzab*

The human brain has the remarkable ability to recognise specific objects, even when those objects change in appearance. For example, we can tell that a hand is a hand regardless of its colour, size, location or orientation.

When processing visual information, brain cells respond to specific features that are important to an object's identity – that is, they display feature selectivity. At the same time, the cells ignore features that are not important – they are invariant to feature manipulation. Combining selectivity and invariance is crucial for visual processing, but how the brain does this was not well understood.

To answer this question, a team of Brain Function CoE researchers, led by Ali Almasi from the National Vision Research Institute of Australia and Hamish Meffin from the University of Melbourne, studied cells in the primary visual cortex (V1). This region of the brain is responsible for the first stage of visual processing in the cortex.

The researchers measured how the activity of cells in the V1 changed when the cells received visual information about 'white noise' – random combinations of black and white pixels arranged in a square grid.

Because the images of white noise are random, patterns can emerge in the pixels – such as horizontal or vertical stripes. The researchers used the brain activity data to map how the cells responded to different combinations of patterns.

The researchers built a computer model to estimate the cells' selectivity and invariance to particular features of the different patterns, such as their orientation, frequency and phase. For a striped pattern, these features would describe whether the stripes were horizontal or vertical, how tightly spaced they were, and whether the pattern started with a black stripe or a white one.

The model revealed that most cells had a high degree of selectivity and a low degree of invariance for both orientation and frequency. However, the cells varied in their response to phase – some cells were highly selective, whereas others were completely invariant.

These findings show that even at a stage of visual processing as early as V1, the brain forms an elaborate set of sensitivities to generic features. These form the basis of more sophisticated processing in other visual areas of the brain.

### Next steps

The researchers plan to study how these selective and invariant properties develop in other regions of the brain.

*Reference:*  
Almasi, A., Meffin, H., Cloherty, S.L., Wong, Y., Yunzab, M., & Ibbotson, M. R. (2020). Mechanisms of feature selectivity and invariance in primary visual cortex. *Cerebral Cortex*, bhaa102. doi: 10.1093/cercor/bhaa102

## 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*

**In a nutshell: Researchers have discovered that the prefrontal cortex and the hippocampus play a role in processing and/or recognising novel surroundings.**

As cortical processing reflects the interplay between excitation and inhibition, knowledge of the heterogeneous distribution of subtypes of interneurons and pyramidal neurons 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.

Two different methods were initially utilised to show that prefrontal cortex (PFC) neurons and hippocampal neurons are active during the cognitive task, known as novel object recognition (NOR). These are electrophysiological recordings (Sah lab) and immunohistochemistry (Paxinos lab). There is now enough data from our NOR investigation to form two separate research publications. The findings are as follows:

(1) The Sah lab 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. This project formed the basis of another collaborative project between Sah lab and Arabzadeh lab (ANU). This year the Sah lab will use optogenetic to silence the hippocampal to PFC projection during NOR to demonstrate that the PFC and hippocampus interact to drive object recognition. This will be written up for publication and reported to the Centre by the Sah lab.

(2) In addition, the Paxinos lab used immunohistochemistry for the neuronal activity marker, c-Fos, to identify the precise brain region of the activity. We demonstrated that c-Fos is up-regulated in PFC when a novel object is explored compared to a familiar object at test. We also extended the scope of investigation and demonstrated the up-regulation of c-Fos in the PFC during acquisition of NOR. Importantly, we also examined the hippocampus and demonstrated that c-Fos is upregulated in this brain region during both the acquisition and expression of NOR. These findings suggest that the PFC and the hippocampus have a role in processing and/or recognising novelty.

### Next steps

To determine whether the active cells in the cortex are inhibitory or excitatory.



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.

## The fractal properties of brain activity are part of a bigger picture

*Investigators: Paul Martin, Pulin Gong, Brandon Munn, Natalie Zeater, Alexander Pietersen, Sam Solomon*

### **In a nutshell: In the primate visual system, fractal-like patterns of activity are found in brain cells that help to detect danger.**

The brain processes information by sending electrical signals between cells. The patterns of electrical activity – also called spike patterns – change depending on the type of brain cells involved and what function the brain is performing at the time.

It is now known that the spike patterns of individual cells can have a fractal quality – that is, they have similar properties whether you zoom in to look at a specific detail or zoom out to look at a much larger scale. Fractal patterns are common in nature – just think of the patterns in snowflakes, clouds, or Romanesco broccoli – and recent discoveries show that they might also be an important part of brain activity.

To understand why fractal-like patterns are important, Brain Function CoE researchers, led by Pulin Gong and Paul Martin at the University of Sydney, analysed cells in the early visual system – the parts of the brain involved in processing visual information.

They measured the spike patterns of single cells from two vision-related areas of the brain in marmoset monkeys: the lateral geniculate nucleus (LGN) and the medial temporal visual cortex (MT). Then, they analysed the patterns using methods

that they had developed to detect the statistical fingerprints of fractal activity.

The LGN is made up of three cell types. M-cells are involved in perceiving movement and depth. P-cells have a role in sharp vision. There are different kinds of K-cells; some respond to flashing or moving stimuli, possibly helping us to respond rapidly to nearby threats.

The researchers’ analysis showed that K-cells had more fractal-like spike patterns than P-cells or M-cells. And the spike patterns of MT cells were even more fractal-like than those of K-cells.

“Fractal brain activity is more flexible than constant brain activity, especially in an unpredictable environment”, explains Pulin Gong. The researchers believe that the fractal quality of spike patterns may enable brain activity to change efficiently in response to irregular threats in the animal’s environment, such as the sudden appearance of predators.

### Next steps

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

*Reference:  
Munn, B., Zeater, N., Pietersen, A. N., Solomon, S. G., Cheong, S. K., Paul R. Martin, P. R., & Gong, P. (2020). Fractal spike dynamics and neuronal coupling in the primate visual system. *Journal of Physiology* 598(8), 1551–1571. doi: 10.1113/JP278935*



## Cellular and circuit mechanisms underlying sensory processing in cortex

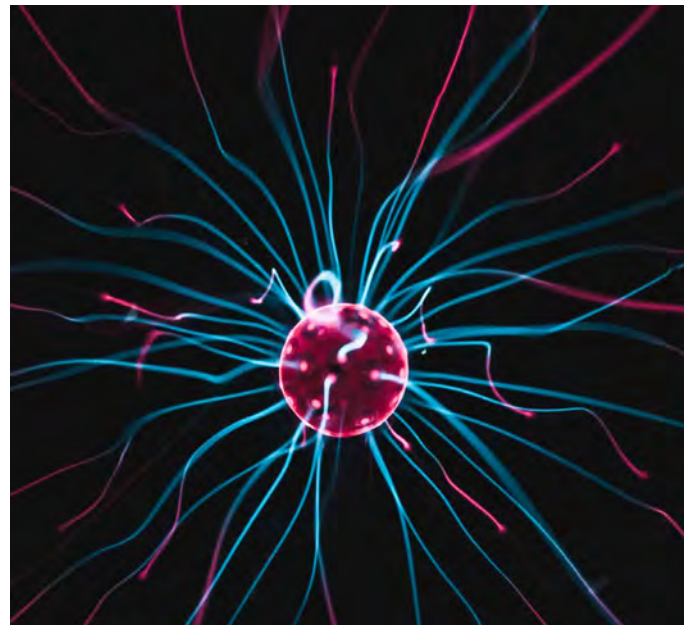
Investigators: Ehsan Arabzadeh, Greg Stuart, Jason Mattingley, Marcello Rosa, Nicholas Price, Mathew Diamond, Vincent Daria, Saba Gharaei, Ehsan Kheradpezhough, Robin Broersen, Matthew Tang, Guthrie Dyce, Suraj Honnuraiah, Taylor Singh, Conrad Lee, Ben Mitchell, Shuang Jiang, Lachlan Owensby

**In a nutshell: While it has long been known that the cortex modulates activity in superior colliculus, we now show that superior colliculus modulates activity in the cortex.**

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 photon calcium imaging of single cells and neuronal for such investigation. This project combines two- 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.

Our recent *Nature Communications* paper demonstrated that optogenetic activation of superior colliculus impacts on cortical processing of whisker inputs to barrel cortex via the thalamic nuclei PoM. Other work investigated how brain state affects cortical processing of sensory information. This research involved a collaboration with PI Diamond and was recently published in *Cell Reports*.

### Next steps

The next step is to investigate the impact of the superior colliculus on perceptual processing as mice engage in a sensory decision task. We also plan to investigate how spatial attention affects the efficiency of sensory processing in the cortex.

*Reference*  
Gharaei S., Honnuraiah, S., Arabzadeh, E., Stuart, G.J. (2020). Superior colliculus modulates cortical coding of somatosensory information. *Nat Commun*, 11: p. 1693. 10.1038/s41467-020-15443-1.

Lee, C.C.Y., Kheradpezhough, E., Diamond, M.E., Arabzadeh, E. (2020). State-dependent changes in perception and coding in the mouse somatosensory cortex. *Cell Rep*, 32(13): p. 108197. 10.1016/j.celrep.2020.108197

**Researchers have discovered a novel activity pattern in fear-related brain regions, and have introduced behaviour-specific "tagging" of neurons to determine distinct neural circuits to drive these behaviours.**

## Neural circuits that mediate fear learning and extinction

Investigators: Pankaj Sah, Roger Marek, Madhusoothanan Bhagavathi Perumal, Lei Qian, Yajie Sun, 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 as 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 affects 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. Moreover, we have introduced behaviour-specific "tagging" of neurons to determine distinct neural circuits to drive these behaviours.

### Next steps

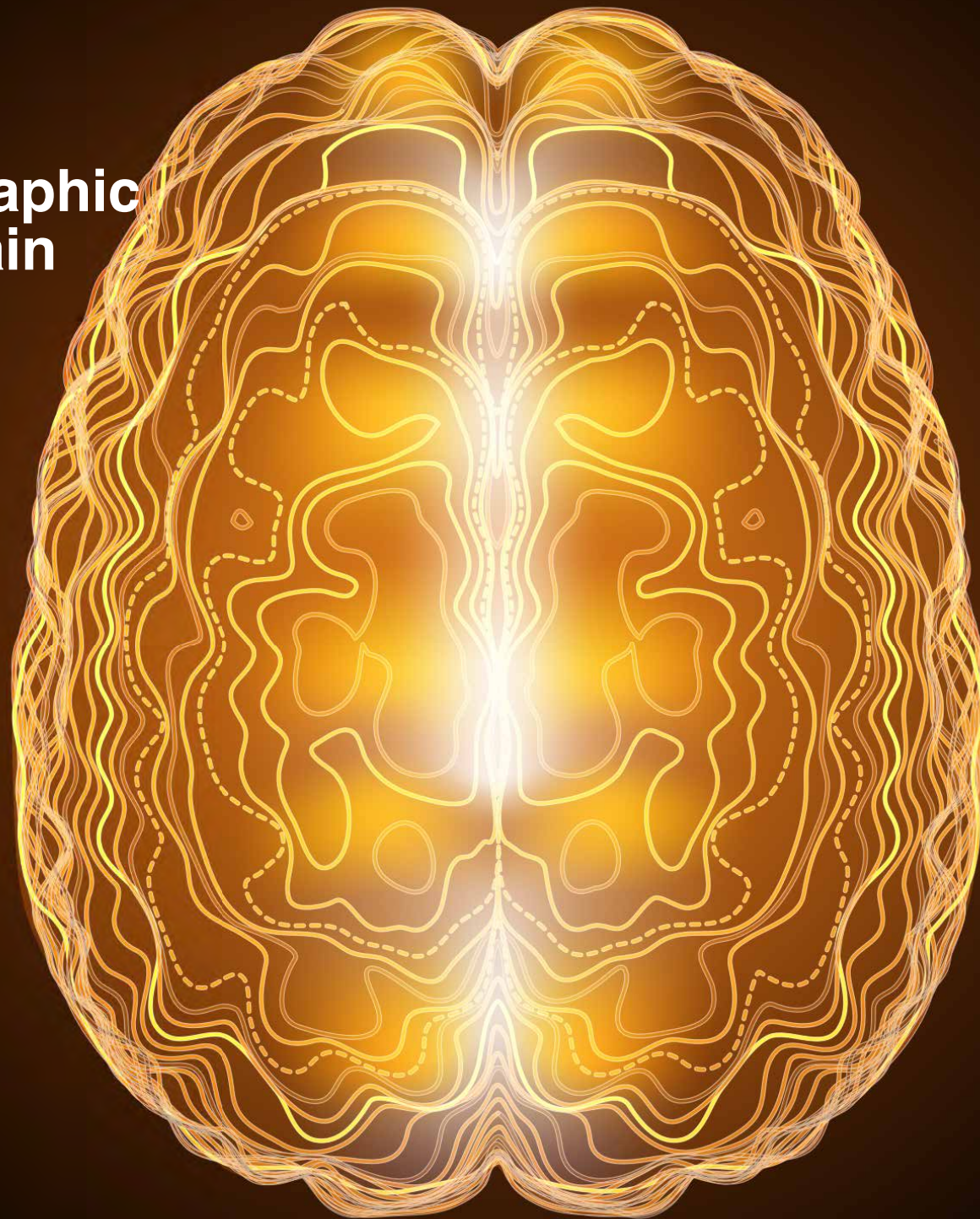
To translate animal model to humans to investigate emotional learning in a paradigm that allows an investigation of direct and indirect neural projections to the amygdala that regulate the recognition of fear cues.

*Reference: Sun, Y., Qian, L., Hunt, S., et al. (2020). Somatostatin neurons in the central amygdala mediate anxiety by disinhibition of the central subnucleus extended amygdala. Mol Psychiatry. 10.1038/s41380-020-00894-1.*



# Twisted topographic maps in the brain

Researchers have identified a new type of visual representation in the brain, using modelling and electrophysiological techniques.



When the brain processes visual information, it breaks each image down into pieces. Each piece is analysed by a different group of brain cells in the visual cortex. The cells that analyse adjacent pieces of the image are next to each other in the brain. This means that what we see is essentially 'mapped' onto our visual cortex.

Traditionally, these so-called topographic maps have been classified according to whether they represent visual information as a mirror image or a non-mirror image of what you see. This classification is widely used to determine the transition between areas in the visual cortex.

Now, researchers have identified a third type of map that combines both types of representation within a single area.

Led by Brain Function CoE investigators Marcello Rosa and Elizabeth Zavitz from Monash University, in collaboration with IBM Research, the researchers modelled how topographic maps are formed during brain development. For the first time, they investigated what happens when two maps develop in adjacent areas, which is common in the brain.

The researchers found that some configurations of areas led to a previously unknown, 'twisted' type of map, which combines regions that represent images as both mirror images and non-mirror images. Using advanced electrophysiological techniques, they showed that this type of map actually exists in the primate brain.

The primate cortex is separated into dozens of visual areas that form a mosaic of individual visual maps. This study demonstrates that the formation of two adjacent areas can create new types of organization that would not be predicted by modelling the formation of each area independently.

This means that to capture the full complexity of the human brain, it will be necessary for models to incorporate multiple areas of the brain and take into account the fact that they develop at different times.

In the next steps, the team is planning to create a more comprehensive model that incorporates information about the sequence of development of areas across the entire visual cortex. They can then use this model to simulate the formation of maps. This will be important to understand differences in the organisation of the cortex between species, including humans.

*Investigators: Marcello Rosa, Elizabeth Zavitz, Hsin-Hao Yu, Declan Rowley, Nicholas Price*

How does our brain process visual information?



Each image is broken into pieces and **analysed by different cells**, joining together to form a map - either a **mirror** image or **non-mirror** image map.

But what happens when two 'maps' develop side by side?



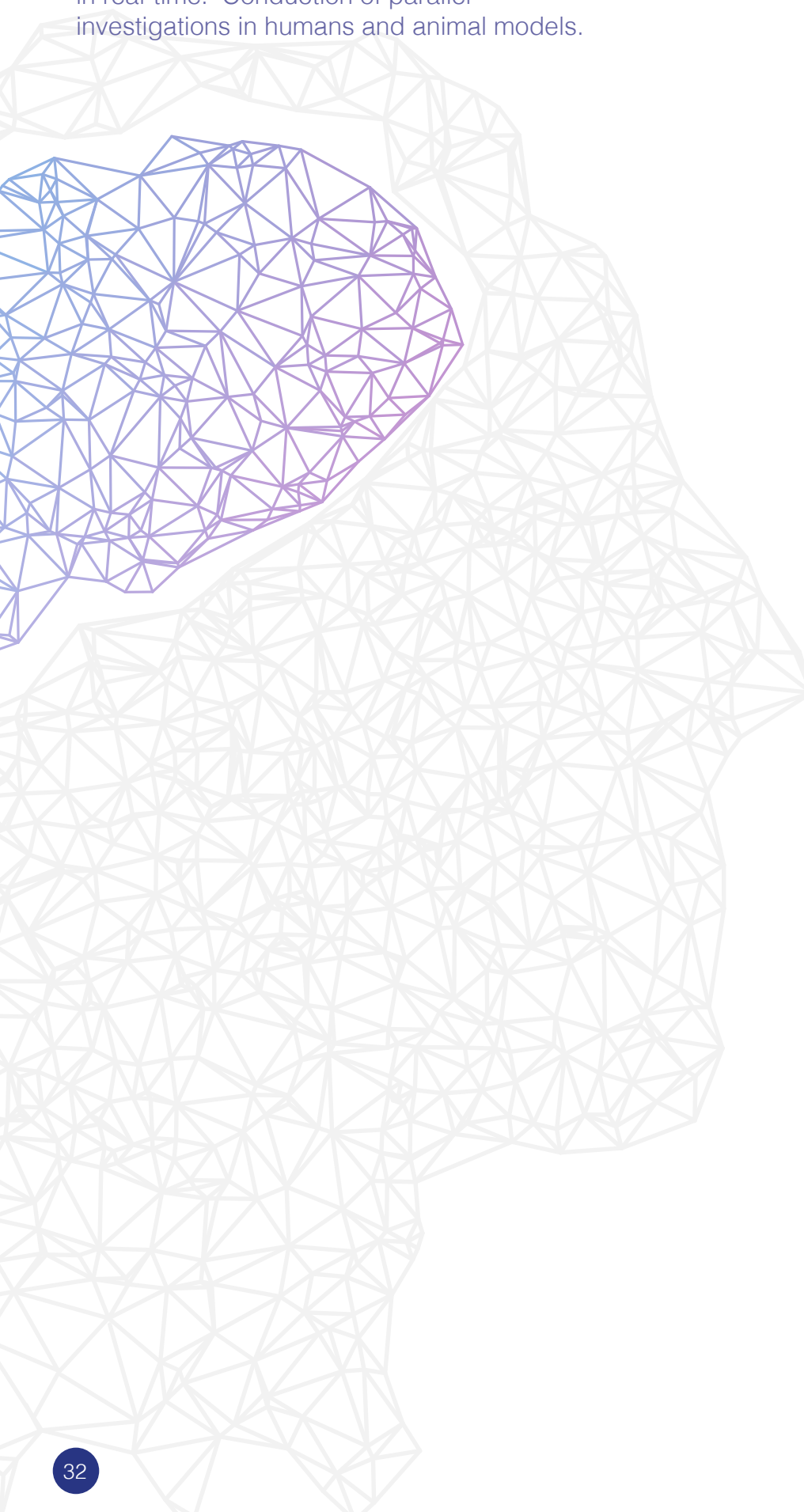
Researchers from the Centre and IBM have discovered a **third 'twisted' map**, which **combines the mirror and non-mirror images**.

So how is this significant? The results reveal a new **path to organising information** in the brain that is **not captured when studying each area independently**.

More research will lead to a better **understanding of the entire visual cortex** and the formation of visual maps in humans.



Research into the coordination of activity across different areas of the mammalian brain in real-time. Conduction of parallel investigations in humans and animal models.



## Attention and decision-making are closely related

*Investigators: Jason Mattingley, Dragan Rangelov*

### **In a nutshell: New research disproves a commonly held belief that attention and decision-making are two independent processes.**

We constantly adapt our behaviour in response to our surroundings. In each situation, we decide on the appropriate response by processing sensory information – such as what we see or hear around us. Processing irrelevant or distracting stimuli may lead to errors, so it is essential that the brain pays attention to relevant stimuli only and disregards other sensory input.

For example, when deciding whether to cross a busy road, we pay attention to traffic signals and cars to our left or right. But we disregard the movement of pedestrians or objects around us. We continue to process this sensory input until we have enough relevant information to make a decision.

Most neuroscience research on attention and decision-making has examined these two processes independently. Little was known about whether, or how, they interact.

To find out, Brain Function CoE investigators Dragan Rangelov and Jason Mattingley from the University of Queensland designed an experiment that required people to pay attention and make decisions at the same time.

Participants performed a simple visual task as their brain activity was monitored using electroencephalography. They viewed a computer screen showing two fields of moving dots – the target and the distractor. The two fields overlapped, were coloured differently, and moved in different directions. The participants were asked to focus their attention on the target field and to report what direction it moved in.

In principle, participants could first identify the target by its colour, and then decide what direction it moves in. In this case, the movement of the distractor should not influence the participants' decision.

Contrary to this expectation, the results showed that the movement of the distractor influenced the participants' decisions about the target motion. It also affected their associated brain activity.

This means that even when the participants paid attention only to the target, their brains still processed some information about the distractor. It also suggests that paying attention to relevant stimuli and deciding on the appropriate response happen at the same time.

In contrast to previous research, which assumed that attention and decision-making are relatively independent, the results of this study show that they are closely related.

### Next steps

The researchers plan to study what happens at the cellular level when attention and decision-making interact. They will also use computational modelling of behaviour and corresponding brain activity to learn more about the processes in the brain that support both selective attention and accurate decision-making.

*Reference:  
Rangelov, D., & Mattingley, J. B. (2020). Evidence accumulation during perceptual decision-making is sensitive to the dynamics of attentional selection. *NeuroImage*, 117093. doi: 10.1016/j.neuroimage.2020.117093*



# Blink and you'll miss it

A new method for measuring rapid brain activity helps to explain why our brains can't process many things at once.

When people are asked to monitor a rapid stream of images for two target objects, they will almost always spot the first target. However, if the second target is presented soon afterwards – as little as 200–500 milliseconds later – they will often have no conscious awareness of it. It's as if their attention has blinked and missed it.

Neuroscientists thought that this phenomenon – known as 'attentional blink' – might be a result of the brain reaching the limit of its attention capacity. But it was difficult to study in detail, because brain imaging methods weren't sensitive enough to measure activity at such short time scales.

A research team led by Brain Function CoE researcher Matthew Tang, then in Jason Mattingley's group at the University of Queensland and now at Australian National University, developed a new experiment and imaging method to look at what happens in the brain during attentional blink.

The researchers showed participants a rapid stream of images on a screen. All the images featured parallel stripes pointing in different directions. In the two target images, the stripes were narrower and closer together. While the participants watched the screen, their brain activity was monitored using electroencephalography (EEG) – a non-invasive brain monitoring technique. After they had viewed all the images, they were asked to report the direction of the stripes in the two target images – either by remembering or by guessing.

The researchers found that participants' recollection of each target was affected not just by the target itself, but also by images they saw immediately afterwards. This suggests that as soon as we pay attention to something, the brain starts to integrate the visual information that follows, even if it is not relevant.

Thanks to their new experimental approach, the researchers were able for the first time to determine which images the brain was processing. They did this by combining statistical analyses with the EEG recordings to decode the direction of the stripes in each image. When participants recalled the second target correctly, the researchers could accurately decode the direction from the EEG recording. However, when participants missed the second target, the quality of the decoding was significantly worse, even poorer than for non-target images.

Based on their results, the researchers believe that attentional blink is caused by the brain balancing demands on its limited resources. As soon as the brain processes the first target, it can focus attention on the second target, allowing us to become aware of it and remember it. But if the second target appears while the first target is still being processed, then the brain actively suppresses information about the second target to avoid it interfering with the first target.

In the next steps the researchers would like to determine whether the attentional blink exists in mice. If it does, they will record the activity of cells in different regions of the mouse brain to study how these regions work together to control visual attention.

*Investigators: Matthew Tang, Lucy Ford, Ehsan Arabzadeh, James Enns, Troy Visser, Jason Mattingley*

What is attentional blink and how does it work?



**Attentional blink** occurs when our brains don't register all images presented in very quick - millisecond quick - succession.

But this is **difficult to accurately measure** with current brain imaging technology **not sensitive enough** at these time scales

A new experimental approach involving **EEG monitoring** while participants **watch images with directional stripes fly by**, has provided some answers.



When asked to **report the direction of the stripes**, recollection was **impacted by the images straight after** the target image.

Our brains **cope with large information demands** by **actively suppressing** new information (or targets) if it is still processing an existing 'target'.





## Primates form and use abstract rules

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

### In a nutshell: A new theoretical framework describes how humans and other primates use the prefrontal cortex to make and update the rules that guide their behaviours.

To perceive our surroundings and help us respond appropriately, our brains use abstract rules and categories to classify objects and events based on past experience.

For example, imagine arriving in a new city for the first time. Maybe you want to find something to eat, take a bus somewhere else, or explore. Using abstract rules, your brain can efficiently classify and group novel objects into behaviourally relevant categories to help you satisfy your current or future needs.

Without these rules, the brain would need to analyse every piece of information and compare it to every other piece of information that it has stored. Apart from taking a huge amount of brain power, this would make it impossible to ever react quickly to anything.

Abstract rules and categories give structure to our perception and thinking. They underpin many of our behaviours, such as planning, social interaction, reasoning and flexibility in adapting to new situations. Difficulties in creating these rules and using them properly have been linked to neuropsychological disorders such as autism spectrum disorder and schizophrenia.

When and how abstract rules emerge in the brain are therefore a topic of extensive research and debate. There is growing evidence that the prefrontal cortex has an important role in humans and non-human primates. However, damage to this region of the brain does not necessarily impair rule-dependent behaviour.

### Next steps

The researchers hope to study in more detail what brain mechanisms contribute to the formation and use of abstract rules.

Reference:  
Mansouri, F. A., Freedman, D. J., Buckley, M. J. (2020). Emergence of abstract rules in the primate brain. *Nature Reviews Neuroscience*, doi: 10.1038/s41583-020-0364-5

In a recent article in *Nature Reviews Neuroscience*, Brain Function CoE researcher Farshad Mansouri and colleagues propose a framework for how abstract rules are formed and used in the primate brain.

They describe different types of rules, such as object matching versus non-matching, colour matching versus shape matching, and matching the number of items. For each type, they review evidence from human and animal studies to determine similarities and differences between species.

Based on this knowledge, the authors propose that abstract rules emerge from a dynamic, multi-stage process involving different brain mechanisms and memory. In this process, the prefrontal cortex is involved in forming, storing, retrieving and updating rules. In stable environments, the rules are reinforced, and little prefrontal cortex involvement is required. In new or changing environments, however, the rules are continually formed and updated. This requires more cognitive resources and the contribution of the prefrontal cortex.

This framework helps to explain the role of the prefrontal cortex in the emergence and implementation of abstract rules for controlling primate behaviour.

## A new open dataset for studying the brain

Investigators: Gary Egan, Sharna Jamadar, Phillip Ward, Alex Fornito

### In a nutshell: The publicly accessible Monash rsPET-MR dataset will help researchers to understand network dynamics in the brain.

The Monash rsPET-MR dataset was generated by Brain Function CoE investigators Sharna Jamadar and Phillip Ward, in collaboration with colleagues from Monash University and Siemens Healthineers.

It includes data on brain activity that was captured from 27 healthy young adults using two methods applied simultaneously. These methods measure the two main sources of energy in the brain. The 'rs' in the dataset name refers to 'resting state', as the volunteers were measured as they lay awake with their eyes open.

BOLD-fMRI (blood oxygen level-dependent functional magnetic resonance imaging) measures oxygen use in the brain. FDG-PET ([<sup>18</sup>F]-fluorodeoxyglucose positron emission tomography) measures glucose use in the brain. The team used a new technique, 'constant infusion', which allows a PET measure to be taken every 16 seconds. The standard approach can take 10–30 minutes to provide a single PET measure.

Using these two techniques simultaneously, the physiological processes underlying brain activity can be examined from multiple sources at the same time. This approach can also be used to measure changes in brain activity in response to certain tasks or at different stages of rest.

Since simultaneous fPET-fMRI is a new technology, few biomedical imaging facilities worldwide have produced datasets like this one. As a result, the researchers have publicly released the Monash rsPET-MR dataset for the use of the neuroimaging community. It is freely available from the OpenNeuro repository.

Researchers in the brain imaging community can use this unique dataset to understand the relationship between oxygen and glucose use during dynamic brain function. They can also use it to develop new methods and scientific discoveries.

### Next steps

The team is now exploring how to provide the dataset to the community in a standardised format, to make it easier to use the data.

Reference:  
Jamadar, S. D., Ward, P. G. D., Close, T. G., Fornito, A., Premaratne, M., O'Brien, K., Stäb, D., Chen, Z., Shah, N. J., Egan, G. F. (2020). Simultaneous BOLD-fMRI and constant infusion FDG-PET data of the resting human brain. *Scientific Data*, 7, 363. doi: 10.1038/s41597-020-00699-5





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

## Haemoglobin levels affect the results of brain connectivity studies

*Investigators: Gary Egan, Phillip Ward, Sharna Jamadar, Edwina Orchard, Alex Fornito, Stuart Oldham*

### **In a nutshell: Natural variations in haemoglobin levels should be considered when using functional MRI to study brain connectivity.**

The functional connectome is a map of all the connections used in the brain to communicate between cells. To determine the functional connectome and link it to brain activity, researchers often use functional magnetic resonance imaging (fMRI).

When brain cells become active, they need more oxygen. This increases blood flow to that part of the brain. It also changes the ratio of oxygenated to deoxygenated haemoglobin in the blood. The fMRI technique measures brain activity by detecting these changes.

However, haemoglobin levels are influenced by many factors other than brain activity – such as a person's sex, age, race or stress levels. New research shows that these variations can affect fMRI-based studies of functional connectivity.

The team of researchers from Monash University, led by Brain Function CoE investigators Philip Ward and Sharna Jamadar, looked at individual differences in haemoglobin levels in a group of healthy older adults. The researchers split data from 518 participants into four groups: males and females with either a high or a low haemoglobin level. Then they compared the participants' fMRI measurements to see if group differences influenced how the functional connectome was determined.

### Next steps

Blood haemoglobin levels are currently estimated from samples obtained by pricking a finger. The researchers are considering ways to estimate haemoglobin from the fMRI images themselves.

*Reference: Ward, P. G. D., Orchard, E. R., Oldham, S., Arnatkeviciute, A., Sforazzini, F., Fornito, A., Storey, E., Egan, G. F., & Jamadar, S. D. (2020). Individual differences in haemoglobin concentration influence BOLD fMRI functional connectivity and its correlation with cognition. *Neuroimage*, 221, 117196. doi: 10.1016/j.neuroimage.2020.117196*

In males, differences in haemoglobin levels affected how functional connectivity was measured across the whole brain. In females, however, the effect was weaker and more varied.

Compared with high-haemoglobin females, low-haemoglobin females had higher functional connectivity in regions of the brain at the rear of the cortex. But they had lower connectivity in regions in the middle of the brain.

These results show that if researchers do not control for the variability in people's haemoglobin in their analyses, they may come to the wrong conclusions when studying the functional connectome using fMRI.



**In a nutshell: New recommendations for reporting on EEG and MEG experiments aim to improve the reproducibility of neuroimaging research.**

## New recommendations on best practices in neuroimaging research

*Investigators: Marta Garrido and the Organization for Human Brain Mapping*

Neuroimaging has become an integral part of neuroscience research. Non-invasive techniques such as electroencephalography (EEG) and magnetoencephalography (MEG) map human brain activity by recording electrical activity or magnetic fields in the brain, respectively.

To ensure that neuroimaging studies can be reproduced – a fundamental tenet of scientific research – the Organization for Human Brain Mapping has called for standards in how data is acquired, analysed, reported and shared.

The organization's Committee on Best Practices in Data Analysis and Sharing has now released recommendations on best practices in EEG and MEG research.

The recommendations were put together by an international committee of expert researchers, including Brain Function CoE investigator Marta Garrido, who collaborated with the EEG and MEG research communities.

The recommendations include best practices in research methodology and reporting. They outline the basic features of neuroimaging experiments that researchers should describe when reporting on their research. They also promote sharing of data and code.

### Next steps

The recommendations correspond to best practices in 2019 and 2020. They are a 'living' document that can be updated by the research community as the field evolves and new methods and approaches emerge.

*Reference:*  
Pernet, C., Garrido, M. I., Gramfort, A., Maurits, N., Michel, C. M., Pang, E., Salmelin, R., Schoffelen, J. M., Valdes-Sosa, P. A., & Puce, A. (2020). *Issues and recommendations from the OHBM COBIDAS MEEG committee for reproducible EEG and MEG research.* *Nature Neuroscience*, doi: 10.1038/s41593-020-00709-0

## Exciting news about an inhibitory neurotransmitter

*Investigators: Steve Petrou, Alexander Bryson, David Grayden, Sean Hill*

### **In a nutshell: A common neurotransmitter thought to inhibit cell signalling in the brain can also excite certain types of cells.**

Our brains are constantly processing information – such as what we see, hear, or smell – and finding the appropriate response. Brains do this by converting information into an electrical signal, which is transmitted from cell to cell. Everything we do – from sensing our environment, to thinking and then acting – relies on these signals travelling to the right locations in the brain at the right time.

The transmission of signals around the brain is controlled by neurotransmitters. Each brain cell usually has only one type of neurotransmitter – either excitatory or inhibitory. Excitatory neurotransmitters help to spread the electrical signal to other brain cells, whereas inhibitory neurotransmitters stop it from going further.

One of the main inhibitory neurotransmitters in the adult mammal brain is gamma-aminobutyric acid (GABA). Because of the way the brain changes from birth to adulthood, GABA was believed to have excitatory activity in the developing brain before becoming completely inhibitory in the mature brain.

But research from the Brain Function CoE is challenging that view. PhD student Dr Alex Bryson and his supervisor, Professor Steven Petrou from the Florey Institute of Neuroscience and Mental Health, have shown that even in adulthood, GABA can act as both an inhibitory and an excitatory neurotransmitter.

Together with colleagues at The University of Melbourne, they collaborated with researchers from the Blue Brain Project – a Swiss research initiative that aims to build digital reconstructions and simulations of the rodent brain using supercomputers.

Using computer models from the Blue Brain Project, they predicted that GABA might have both inhibitory and excitatory properties. By carrying out lab experiments in adult mice, the researchers confirmed that GABA can, in fact, excite certain types of brain cell.

This unexpected discovery reveals that GABA is more complicated than previously thought. It also gives researchers clues as to how the brain finds the right balance between excitation and inhibition – and how imbalances could potentially be treated.

### Next steps

The researchers plan to explore how different types of brain cells regulate excitatory activity within brain networks. In particular, they want to know how dysfunction of these mechanisms leads to brain disorders such as epilepsy.

*Reference:*  
Bryson, A., Hatch, R. J., Zandt, B.-J., Rossert, C., Berkovic, S. F., Reid, C. A., Grayden, D. B., Hill, S. L., & Petrou, S. (2020). *GABA-mediated tonic inhibition differentially modulates gain in functional subtypes of cortical interneurons.* *Proceedings of the National Academy of Sciences USA*, 117(6), 3192-3202. doi: 10.1073/pnas.1906369117



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

Investigators: Peter Robinson, Pulin Gong, Benjamin Fulcher, Tahereh Janvier-Babaie, Romesh Abeysuria, Kevin Aquino, James Pang, Natasha Gabay, Mariya Ferdousi, Dongping Yang, Kamrun Mukta, Demi Gao, Sahand Assadzadeh, Brandon Munn, Eli Mueller, Xiaochen Liu, Rawan El-Zghir

### In a nutshell: Researchers have developed new techniques that model and analyse the brain that respects its physical and biological boundaries and makes use of analysis methods translated from the physical sciences.

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 has developed 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 realisable 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 systematic and

compact descriptions of brain structure and dynamics and allow deeper understanding in terms of physical brain properties and are currently being applied to understand adaptation during evoked activity and longer-term dynamic connectivity. Outcomes include a physical understanding of the origins of much of the mismatch between responses to common and rare stimuli and a clearer delineation of the contributions of random and systematic changes to functional connectivity dynamics. Application of the evoked-response results to data from Marta Garrido's experiments is anticipated, but has been delayed by the pandemic.

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>

*Reference*  
Babaie-Janvier, T., Robinson, P.A. (2020). Neural field theory of evoked response potentials with attentional gain dynamics. *Front Hum Neurosci*, 14: p. 293. 10.3389/fnhum.2020.00293.

## New electrode technologies for recording network brain activity

Investigators: Michael Ibbotson, Tony Burkitt, Hamish Meffin, Ali Almasi, Shi Sun, Jung Jun, Wei Tong, Stephen Prawer, David Garrett

### In a nutshell: A new carbon-based coating improves the performance of carbon-fibre microelectrodes, enabling two-way communication with single brain cells.

Neural interfaces are implantable devices used for communicating with the brain. By inserting electrodes into the brain, researchers can study how the brain works and develop new therapies for neurological diseases.

But current neural interfaces are limited in their design and application. Most implantable devices communicate with the brain in only one way: they either record or stimulate brain activity. And, because inserting electrodes into the brain can lead to inflammation and scarring, the devices have limited lifespans.

To solve both of these problems, Brain Function CoE researchers from The University of Melbourne, National Vision Research Institute and RMIT University have developed a new coating for implantable devices. The research was led by Wei Tong from Michael Ibbotson's group.

The new coating is made from two-dimensional plates of carbon material, stacked vertically to create 'nanowalls'. When these carbon-based nanowalls are deposited onto the surface of electrodes, they increase their overall surface area. This improves the electrodes' electrochemical properties.

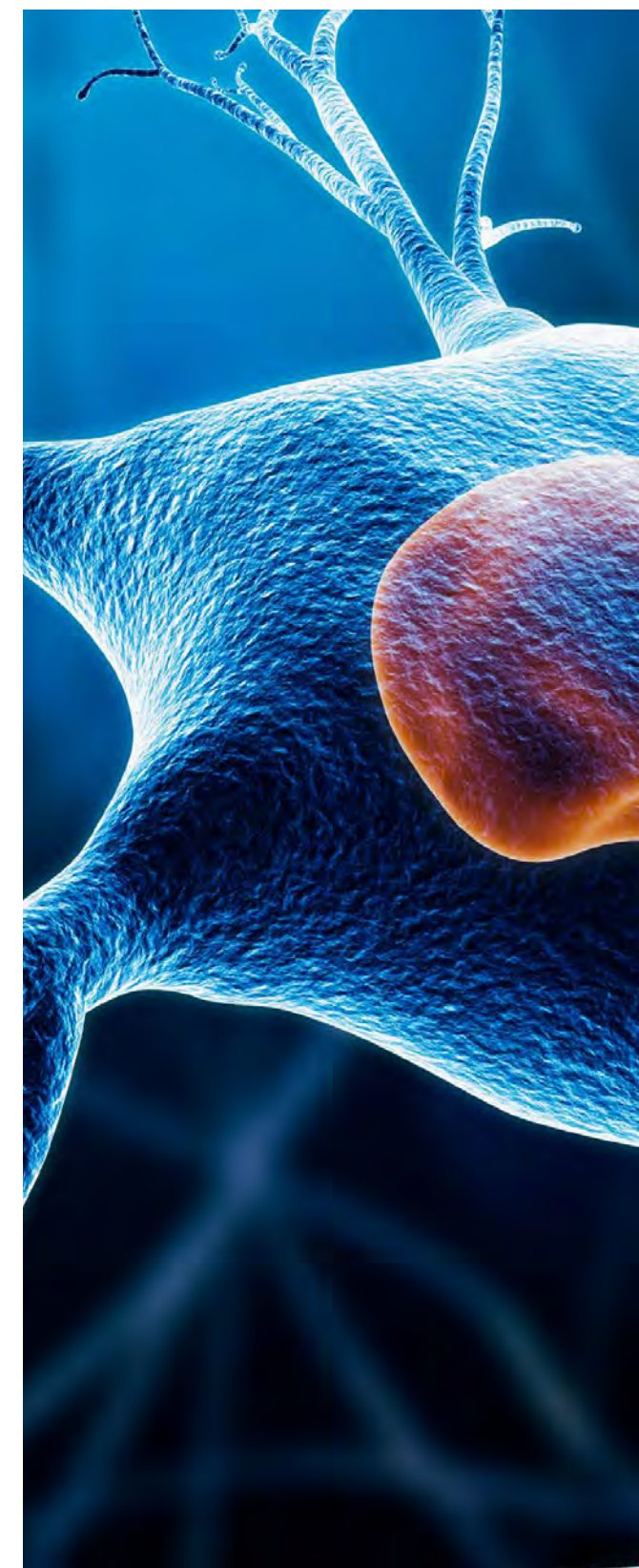
The new coating improved the performance of carbon-fibre microelectrodes. The coated electrodes successfully stimulated cells in retinal tissue. They also recorded activity from single cells in the brain with a high signal-to-noise ratio.

The researchers also showed that the new coating is flexible and does not peel or crack when the electrodes are bent. Coated electrodes are still ultrathin, so they create minimal damage to the brain during insertion. And because the nanowalls are made from a carbon material, the immune system does not treat them like a foreign substance. This reduces the likelihood of scarring, enabling long-term use of the coated electrodes.

### Next steps

The researchers plan to demonstrate the safety and function of the coated electrodes in rodents over extended periods, such as six months or more.

*Reference*  
Hejazi, M. A., Tong, W., Stacey, A., Sun, S. H., Yunzab, M., Almasi, A., Garrett, D. J. (2020). High fidelity bidirectional neural interfacing with carbon fiber microelectrodes coated with boron-doped carbon nanowalls: An acute study. *Advanced Functional Materials*, 2006101. doi: 10.1002/adfm.202006101





## HIGHLIGHTS

2 BOOKS  
2 BOOK CHAPTERS



70 JOURNAL ARTICLES



13  
ARTICLES PUBLISHED IN  
JOURNALS WITH AN IF>10

11  
ARTICLES (16%) PUBLISHED  
IN NATURE JOURNALS

## NOTABLE ACHIEVEMENTS (by publication number)

22. Garner et al. published on remediation of cognitive capacity limits, receiving an **Altmetric score of 124**, ranking it in the top 5% of all research outputs scored by Altmetric. This paper was also of interest to the media, with news stories published in **ten different news outlets across the globe**.

23. Gharaei et al. published on modulation of cortical coding of somatosensory information, in **Nature Communications, a top ten-ranked journal** in the field of Biochemistry, Genetics and Molecular Biology.

41. Liu et al. published on 3D mapping of pathways in the marmoset brain, in **Nature Neuroscience, the 2nd ranked journal** in the field of Neuroscience.

45. Mansouri et al. published on the emergence of abstract rules in the primate brain, in **Nature Reviews Neuroscience, the highest ranked journal** in the field of Neuroscience.

46. Masri et al. published analysis of visual pathways in human retina, in **Journal of Neuroscience, a top-ranking journal** in the field of Neuroscience.

47. McFadyen et al. published on subcortical shortcuts influencing disordered sensory and cognitive processing, in **Nature Reviews Neuroscience, the highest ranked journal** in the field of Neuroscience.

53. Pernet et al. published on EEG and MEG research reproducibility, in **Nature Neuroscience, the 2nd ranked journal** in the field of Neuroscience.

57. Rosenfeld et al. published on an intracortical visual prosthesis, receiving an **Altmetric score of 170**, ranking it in the **top 5%** of all research outputs scored by Altmetric. This paper was also of interest to the media, with news stories published in **20 different news outlets across the globe**.

70. Tekieh et al. published on visual field map prediction in the **Journal of Pineal Research, a top 10 ranked journal** in the field of endocrinology.



(Roll over for highlights)

## Books

1. Mai, J., Majtanic, M., Paxinos, G. (2020). *Atlas of the Human Brain*, 4th ed. San Diego: Academic Press.
2. Paxinos, G., Halliday, G., Watson, C., et al. (2020). *Atlas of the Developing Mouse Brain*, 2nd ed. San Diego: Academic Press.

## Book chapters

3. Gharaei, S., Stuart, G.J., Arabzadeh, E. (2020). Collicular Anatomy and Function, in *The Senses: A Comprehensive Reference*, B. Fritzsche (Ed). Netherlands: Elsevier. p. 549-566.
4. Ibbotson, M.R., Meffin, H. (2020). Visual Information Processing, in *The Senses: A Comprehensive Reference*, B. Fritzsche (Ed). Netherlands: Elsevier. p. 36-53.

## Journal articles

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6. Almasi, A., Meffin, H., Cloherty, S.L., et al. (2020). Mechanisms of feature selectivity and invariance in primary visual cortex. *Cereb Cortex*, 30(9): p. 5067-5087. 10.1093/cercor.bhaa102.
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## International Presentations

1. Adibi, M., Nematollahzadeh, F., Yazdian, E. The link between the spatiotemporal dynamics of mesoscale and microscale activity in sensory cortex. *43rd Annual Meeting of the Japan Neuroscience Society JNS2020*. Virtual, Japan. 29 Jul-1 Aug 2020.
2. Almasi, A., Meffin, H., Sun, S.H., et al. How stimulus affect the receptive fields of cells in primary cortex. *29th Annual Computational Neurosciences Meeting*. Virtual, International. 18-22 Jul 2020.
3. Arabzadeh, E. Neural coding. *Webinar on Advanced Electrophysiology*. Virtual, Iran. 14 Oct 2020.
4. D'Souza, J.F., Cloherty, S.L., Price, N.S.C., et al. Spatial cueing reduces marmoset reaction times in a six-target centre-out saccade task. *Marmoset Bioscience Symposium*. Virtual, International. 18-22 Jul 2020.
5. Fulcher, B.D. A practical guide to working reproducibly. *OHBM Australian Chapter Webinar*. Virtual, Australia. 26 May 2020.
6. Fulcher, B.D. Characterizing neural dynamics using highly comparative time-series analysis. *29th Annual Computational Neurosciences Meeting*. Virtual, International. 18-22 Jul 2020.
7. Garner, K., Barth, M., Garrido, M. 7T Sequences for imaging the basal ganglia. *Neuromatch Computational Neuroscience*. Virtual, International. 26-30 Oct 2020.
8. Garrido, M. From prediction errors to computational psychiatry. *Computational Psychiatry Course Zurich*. Virtual, Switzerland. 7-12 Sept 2020.
9. Grünert, U. Neural circuitry of rod mediated vision. *Association for Research in Vision and Ophthalmology Education Course: Night vision in aging, AMD, and beyond: basic and clinical aspect*. Virtual, International. 2 May 2020.
10. Hagan, M.A. Untangling the laminar architecture of feedforward inputs: marmosets as a model for studying neural communication. *Marmoset Bioscience Symposium*. Virtual, International. 22 Oct 2020.
11. Ibbotson, M.R. Early visual pathway. *Machine Intelligence and Brain Research Winter Course/Workshop on Computational Brain Research at IIT Madras*. Chennai, India. 2-10 Jan 2020.
12. Jamadar, S. Introduction to functional MRI. *European Summer School on Eye Movements*. Virtual, International. 7-11 Sept 2020.
13. Kalhan, S., McFadyen, J., Tsuchiya, N., et al. Neural correlates of accelerated perceptual awareness: A 7T-fMRI study. *New Horizons in Human Brain Mapping*. Hawaii, USA. 4-6 Feb 2020.
14. Mansouri, F.A. Emergence of abstract rule in the primate brain. *International Conference of Basic and Clinical Neuroscience*. Virtual, Iran. Dec 2020.
15. Mattingley, J. Understanding the role of prediction in sensory encoding. *Australasian Cognitive Neuroscience Society Virtual Meeting*. Virtual, Australia. 14 Oct 2020.
16. Nematollahzadeh, F., Yazdian, E., Jalal Zahabi, S., et al. Spatiotemporal dynamics of mesoscale and microscale activity in sensory cortex. *Federation of European Neuroscience Societies Forum 2020*. Virtual, International. 11-15 July 2020.
17. Nematollahzadeh, F., Zahabi, S.J., Yazdian, E., et al. Spatiotemporal dynamics of mesoscale and microscale activity in sensory cortex. *Neuromatch Computational Neuroscience*. Virtual, International. 26-30 Oct 2020.
18. Paxinos, G. Who is the puppet and who is the puppeteer? *Panhellenic Interscience Congress*. Virtual, Greece 25-27 Sept 2020.
19. Randeniya, R., Vilares, I., Mattingley, J., et al. Neural pathways of atypical sensory learning in Autism. *New Horizons in Human Brain Mapping*. Hawaii, USA. 4-6 Feb 2020.
20. Rangelov, D. Organize your data according to the Brain Imaging Data Structure (BIDS) - your future self will thank you! *OHBM Brainhack 2020*. Brisbane, Australia 17 May 2020.
21. Robinson, P.A., Gao, X., Han, Y. Relationships between lognormal distributions and neural properties and connectivities. *American Physical Society*. Virtual, USA. 2-6 Mar 2020.
22. Sah, P. Circuit mechanisms that mediate sharp wave oscillations in the amygdala. *Global Artificial Intelligence Technology Conference*. Virtual, China. 26 Jul 2020.
23. Stuart, G. Cellular and circuit mechanisms underlying binocular vision. *9th Basic and Clinical Neuroscience Congress*. Virtual, Iran. 11 Dec 2020.
24. Almasi, A., Sun, S.H., Yunzab, M., et al. How do stimulus statistics change the receptive fields of cells in primary visual cortex? *Systems & Computational Neuroscience Down Under (SCiNDU)*. Brisbane, Australia. 29-31 Jan 2020.
25. Arabzadeh, E. State modulation of cortical activity. *NeuroSadra Neuroscience Program*. Virtual, Australia. 16 Oct 2020.
26. Arabzadeh, E. Neuroscience of creativity. *School of Music, ANU*. Canberra, Australia. 25 Sept 2020.
27. Dear, M. Naturalistic images in perception and working memory. *QBI Summer Scholars Symposium*. Brisbane, Australia. 7 Feb 2020.
28. Dzafic, I., Garrido, M. Prior belief formation and precision in the schizophrenia spectrum. *Biological Psychiatry Australia*. Virtual, Australia. 19-21 Oct 2020.
29. Jamadar, S. Recent advances in simultaneous MRI-PET. *OHBM Australian Chapter Webinar*. Virtual, Australia. 26 May 2020.
30. Kalhan, S., Garrido, M., Hester, R. Dependent smokers exhibit greater prefrontal cortex activity during preparatory control but blunted anterior cortex activity during reactive control with inhibiting over rewards. *Medicine, Dentistry and Health Sciences Graduate Research Conference*. Virtual, Australia. 26 May 2020.
31. Maljevic, S.C. Patient stem cell-derived neuronal models of SCN2A disorders. *Epilepsy Research Centre Annual Retreat*. Virtual, Australia 1-2 Oct 2020.
32. Mattingley, J. Understanding the role of prediction in sensory encoding. *Institute for Social Neuroscience*. Melbourne, Australia. 27 Aug 2020.
33. Mattingley, J. Understanding the role of prediction in sensory encoding. *QBI Neuroscience Seminar*. Brisbane, Australia. 16 Sept 2020.
34. Mattingley, J. Understanding the role of prediction in sensory encoding. *Systems & Computational Neuroscience Down Under (SCiNDU)*. Brisbane, Australia. 29-31 Jan 2020.
35. Mattingley, J., Stead, I. Understanding cognitive and brain changes throughout adolescence. *Australian Council for Educational Leaders (ACEL)*. Virtual, Australia. 2 Sept 2020.
36. Orchard, E. The neuroscience of late-life parenthood. *Monash Biomedical Imaging Seminar Series*. Virtual, Australia. 12 Nov 2020.
37. Orchard, E. Human motherhood is neuroprotective for the late-life maternal brain. *Monash Neuroscience in a Flash*. Virtual, Australia. 14 Dec 2020.
38. Orchard, E. Human motherhood is neuroprotective for the late-life maternal brain. *Students of Brain Research 2020 Student Symposium*. Virtual, Australia. 2-3 Dec 2020.

39. Robinson, P.A. Interrelating multiscale brain structure and dynamics via modeling. *Monash Biomedical Imaging Seminar Series*. Melbourne, Australia. 17 Feb 2020.
40. Robinson, P.A. Interrelating multiscale brain structure and dynamics via modeling. *University of Melbourne*. Melbourne, Australia. 18 Feb 2020.
41. Sah, P. The science of learning. *Crestmead State School*. Brisbane, Australia. 22 Jan 2020.
42. Wardak, A. Fractional diffusion theory of balanced heterogeneous neural networks. *School of Physics 2020 Symposium*. Sydney, Australia. 4 Dec 2020.

## Poster Presentations

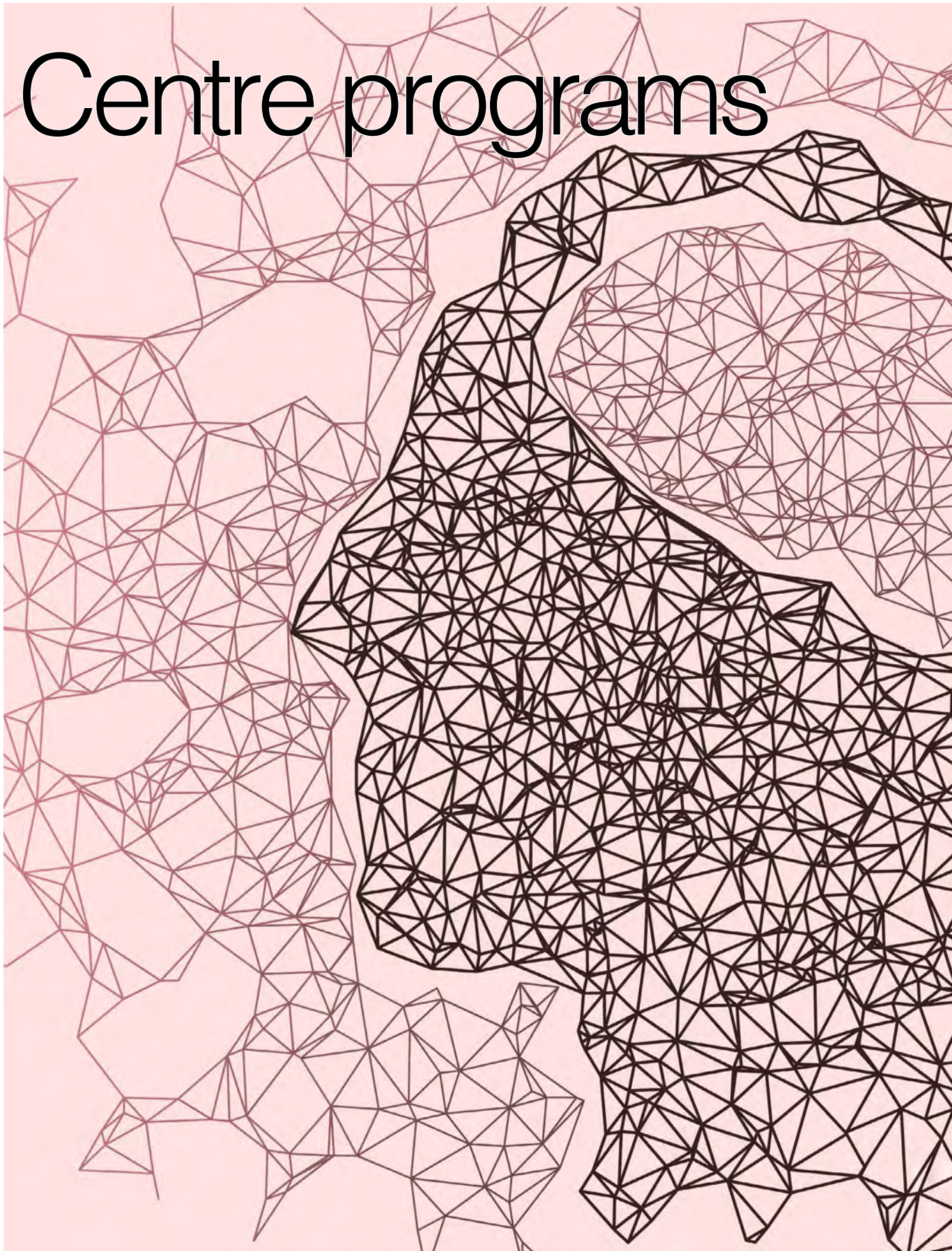
43. Begeng, J., Tong, W., Ibbotson, M.R., et al. Modelling the responses of ON and OFF retinal ganglion cells to infrared neural stimulation. *29th Annual Computational Neurosciences Meeting*. Virtual, International. 18-22 Jul 2020.
44. Chen, G., Gong, P. Dynamical circuit mechanisms of attention sampling. *29th Annual Computational Neurosciences Meeting*. Virtual, International. 18-22 Jul 2020.
45. Cliff, O. Exact inference of linear dependence between auto correlated time series. *29th Annual Computational Neurosciences Meeting*. Virtual, International. 18-22 Jul 2020.
46. Cliff, O., Hernaus, D., Scholtens, L., et al. Modulation of the hierarchical gradient of cognitive information processing dynamics during rest and task. *29th Annual Computational Neurosciences Meeting*. Virtual, International. 18-22 Jul 2020.
47. El-Zghir, R., Gabay, N., Robinson, P.A. Modal-polar representation of evoked response potentials in multiple arousal states. *29th Annual Computational Neurosciences Meeting*. Virtual, International. 18-22 Jul 2020.
48. Eskikand, P.Z., Grayden, D.B., Kameneva, T., et al. A computational neural model of pattern motion selectivity of MT neurons. *29th Annual Computational Neurosciences Meeting*. Virtual, International. 18-22 Jul 2020.
49. Gabay, N., Robinson, P.A., Babaie-Janveier, T. Eigenmodes of cortical activity give rise to cortical standing, traveling, and rotating waves. *29th Annual Computational Neurosciences Meeting*. Virtual, International. 18-22 Jul 2020.



50. Henderson, J.A., Robinson, P.A., Dhamala, M. Brain structure-function relationships via spectral factorization and the transfer function. *26th Annual Meeting of the Organization for Human Brain Mapping*. Virtual, International. 23 Jun-3 Jul 2020.
51. Henderson, J.A., Robinson, P.A., Dhamala, M. Brain dynamics and structure-function relationships via spectral factorization and the transfer function. *29th Annual Computational Neurosciences Meeting*. Virtual, International. 18-22 Jul 2020.
52. Jung, Y.J., Almasi, A., Sun, S.H., et al. Optically imaged map of orientation preferences in visual cortex of an Australian marsupial, the Tammar Wallaby *Macropus eueii*. *29th Annual Computational Neurosciences Meeting*. Virtual, International. 18-22 Jul 2020.
53. Kalhan, S., Garrido, M., Hester, R. Inhibitory control over reward: dependent smokers exhibit more prefrontal cortex activity during preparatory control but reduced anterior cingulate activity during reactive control. *Biological Psychiatry Australia*. Virtual, Australia. 19-21 Oct 2020.
54. Levichkina, E., Mohan, Y.S., Kermani, M., et al. Prediction in vision - elements of predictive coding in awake and anaesthetised primates. *Cognitive Neuroscience Society Annual Meeting*. Virtual, USA. 2-5 May 2020.
55. Liu, X., Robinson, P.A. Analytic model for feature maps in the primary visual cortex. *29th Annual Computational Neurosciences Meeting*. Virtual, International. 18-22 Jul 2020.
56. Long, X., Liu, Y., Marin, P.R., et al. Gamma oscillations organized as localized burst patterns with anomalous propagation dynamics in primate cerebral cortex. *29th Annual Computational Neurosciences Meeting*. Virtual, International. 18-22 Jul 2020.
57. Meffin, H., Almasi, A., Ibbotson, M.R. Contrast invariant tuning in primary visual cortex. *29th Annual Computational Neurosciences Meeting*. Virtual, International. 18-22 Jul 2020.
58. Munn, B., Zeater, N., Pietersen, A.N.J., et al. Gamma-band oscillations, fractal spike dynamics, and population coupling in the primate dorsal lateral geniculate. *Gordon Research Conference 2020 Thalamocortical Interactions*. Ventura, USA. 16-21 Feb 2020.
59. Oldham, S., Fulcher, B.D., Aquino, K., et al. A spatial developmental generative model of human brain structural connectivity. *26th Annual Meeting of the Organization for Human Brain Mapping*. Virtual, International. 23 Jun-3 Jul 2020.
60. Randeniya, R., Vilares, I., Mattingley, J., et al. Bayesian models of atypical perception in Autism. *Cognitive Neuroscience Society Annual Meeting*. Virtual, USA. 2-5 May 2020.
61. Shafiei, G., Vos de Wael, R., Bernhardt, R., et al. Hierarchical organization of local temporal dynamics across the human brain. *26th Annual Meeting of the Organization for Human Brain Mapping*. Virtual, International. 23 Jun-3 Jul 2020.
62. Sun, S.H., Almasi, A., Yunzab, M., et al. Extracellular positive spikes in cat primary visual cortex may correspond from the axons of cells originating in the Thalamus. *29th Annual Computational Neurosciences Meeting*. Virtual, International. 18-22 Jul 2020.
63. Tekieh, T., Robinson, P.A., Lockley, S., et al. Modelling ipRGC-influenced light response on circadian phase, melatonin suppression and subjective sleepiness. *29th Annual Computational Neurosciences Meeting*. Virtual, International. 18-22 Jul 2020.
64. Tong, W., Ibbotson, M.R., Meffin, H. Preventing retinal ganglion cell axon bundle activation with oriented electrodes. *29th Annual Computational Neurosciences Meeting*. Virtual, International. 18-22 Jul 2020.
65. Wainstein, G., Cliff, O., Li, M., et al. Cognitive state and catecholaminergic system modulates cortical information processing dynamics. *26th Annual Meeting of the Organization for Human Brain Mapping*. Virtual, International. 23 Jun-3 Jul 2020.







# Centre programs

## Early Career Researchers

As in previous years, a prominent focus of the Centre of Excellence was to support our Early Career Researchers (ECRs) and promote their career advancement. This year more than ever has seen the need to provide additional assistance to our ECR cohort, with many individuals compromised by COVID-19 and the associated restrictions in place. Many students suffered significant delays in data collection due to stay at home orders, as well as missed opportunities to present research with researchers' scarcity of conference activity. Postdoctoral researcher's employment opportunities were also significantly impacted, with a substantial hiring freeze across the university sector, and international employment opportunities also hampered by travel restrictions. Our ECR Executive committee were faced with the challenge of developing a program to aide career development opportunities and foster career progression in spite of the pandemic.

Members of the ECR Executive Committee were elected at the beginning of the 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 2020 ECR Executive Committee comprised Robin Broersen (ACT), Edwina Orchard (VIC), Anthony Harris (QLD) and Kevin Qu (NSW).



**26**  
Early Career Researchers  
in 2020



**9**  
Female ECRs in 2020



**6**  
Training courses offered  
across the nodes in 2020

## HELPING OUR ECRs WITH COVID-19 SUPPORT FUNDS

The Centre's ECR Executive Committee, alongside the Gender, Equity and Diversity Committee conducted a survey to capture how the COVID-19 pandemic has affected Centre members. As a result of this, an initiative was developed to provide additional scholarship or salary support to those students or postdocs identified as most at risk of food/home/health security from reduced income due to COVID-related delays in their research. Applications were opened to all CIBF Fellows and Scholars, including affiliates, with funding prioritised based on the urgency of identified needs of individuals.

This initiative was designed as a bridging fellowship, to assist PhD students in their final year of scholarship funding who will face a shortfall due to research delays, as well as recently completed PhD students or postdocs who have experienced difficulties finding employment due to hiring freezes and international travel restrictions.

The Centre was proud to support this directive initiated by the ECR Executive committee, ensuring ECRs who were financially impacted by the pandemic had the opportunity to access support.





## Online workshops

The ECR Executive Committee developed a comprehensive program of online webinars targeting wellbeing and resilience building, professional development and career pathways.

Psychologist and career counsellor Dr Shari Walsh was engaged to provide Resilient Researcher, an online workshop designed to enable ECR's to build psychological wellbeing, positive relationships and career confidence, with a focus on time management and stress survival skills. This workshop was followed by A/Prof Inger Mewburn (better known as The Thesis Whisperer), who gave an online seminar entitled "So, you're finishing your PhD in a pandemic. What's next?" This seminar utilised research data on the post-PhD job market to provide insight into the changes in academic employment such as the effects of hiring freezes and travel restrictions; as well as increasing awareness of career opportunities in industry with advice on which sectors are looking for research talent.

The committee also hosted a series of seminars dedicated to pathways to build a successful career. Speakers were invited from fields of academia and industry to share their experiences and possible avenues to reach their professional goals, as well as navigating common obstacles in those fields. These seminars covered topics such as competition in procuring research funding, negotiating projects and roles, the reality of relocation with family, insights into career prospects beyond academia, translational skills from research to industry and the different expectations of academic research versus professional endeavours.

The final focus for the series of online workshops concentrated on the acquisition of research funding. This included a webinar hosted by successful ARC and NHMRC recipients providing an overview of category 1 grant schemes, as well as tips and tricks to preparing a successful application. A separate seminar focussed on looking beyond the typical funding bodies to seek support from as many sources as possible which is particularly relevant at this time of economic uncertainty. They covered alternative funding opportunities from industry or philanthropy, discussing how to approach potential funders, what kind of projects might be appropriate, and some of the pros and cons of non-traditional funding sources. These discussions were followed up with a grant-writing workshops run by GrantEd, which described the best ways for ECRs to 'sell' themselves and their projects, as well as providing personalised feedback on their current funding proposals.

The online workshops and webinars were a huge success, engaging over 460 ECRs across the series. In addition, all online material was recorded and made available for all Centre personnel to access in future.

## ECR seed funding grants

To extend on their theme of acquiring research funding, the ECR Executive Committee allocated a portion of their funds to run their own research grant opportunity. This ECR seed funding grant was a competitive process that provided ECRs with experience of preparing and submitting a grant application. Successful applicants were provided with funds to be spent directly on research expenses for the collection of pilot data, in the hopes that could provide a platform to increase their prospects when applying for subsequent larger grants, in addition to building their individual track record.

All applications were assessed by two members of an independent review panel, with proposals scored on the quality, relevance and feasibility of their project, with preference given to projects that were collaborative in nature. In order to strive for equal opportunity, the applications were assessed solely on the basis of the project, rather than the resume of the applicants. Applications were scored with each of the top three submissions being awarded \$7,500 to complete their proposed projects.

The top three submissions that were awarded funding were Cong Wang from The University of Queensland, who will use her funding to study the cellular mechanisms of prefrontal-hippocampal synchrony mediating recognition memory; Daniel Fehring from Monash University who is studying the neural mechanisms underlying the cognitive effects of prefrontal cortex stimulation; and Timothy Allison -Walker, also of Monash University who will be looking to improve the efficacy of electrical stimulation in the visual cortex to restore vision. All successful applicants have received their funding and will commence their projects in early 2021.

## Mentorship program

Throughout 2020, the ECR Executive Committee facilitated a mentorship network to connect ECRs with each other, and with Chief Investigators and Associate Investigators. This opt-in program encouraged ECRs who wanted to be involved as both a mentor or mentee to self-nominate. All pairings were endorsed by both parties, with pairings based on a multitude of factors including career level, expertise, goals and desired outcomes.

This was a relatively informal process, with the frequency of meetings decided by both parties, along with the goals of the mentorship relationship, with all involved parties providing a personal commitment to the success of the encounter.

The Centre engaged psychologist and career counsellor Dr Shari Walsh to provide Resilient Researcher, an online workshop designed to enable ECR's to build psychological wellbeing, positive relationships and career confidence.







## COVID-19 impacts on our secondary school education program

### Australian and New Zealand Brain Bee Challenge

The COVID-19 pandemic prevented the Centre from hosting the 2020 Australian and New Zealand Brain Bee Challenge, an annual neuroscience competition for students in year 10 in Australia and in year 11 in New Zealand. The competition encourages students to learn about the brain, aiming to inspire students to pursue brain-related careers in medicine and research. We hope to offer the competition again in 2021.

### Brain Bee World Championship

The Australian and New Zealand national winners of the 2019 competition were due to fly to Washington D.C., USA, to compete internationally in the Brain Bee World Championship in August 2020, in conjunction with the American Psychological Association Annual Convention. Unfortunately for the students the COVID-19 pandemic resulted in cancellation of the event. Winners of the 2019 national competition are expected to compete in the International Brain Bee Challenge in 2021.

Why do I love my brain?  
“Because it keeps my  
memories safe”.



Cat 3 3rd place, Skye G

## Primary school creative art competition

The Centre continued its successful drawing competition as part of Brain Awareness Week, 15–21 March 2020. Brain Awareness Week is a global campaign, led by The Dana Foundation, which aims to increase public awareness of the importance and current state of brain research in the world.

To ensure as many children as possible could participate in the 2020 competition, the eligibility criteria was expanded beyond traditional school settings to include home-schooled students and non-formal educational institutions such as Scouts and Guides groups. Due to the COVID-19 pandemic, the entry deadline was extended so that the competition could become a remote learning activity for students.

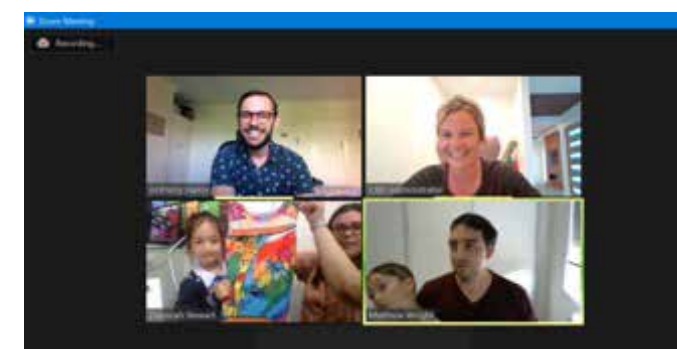
Primary school students from around Australia were invited to submit creative artworks that showed why they love their brain. We received over 650 entries across three categories:

- » 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)

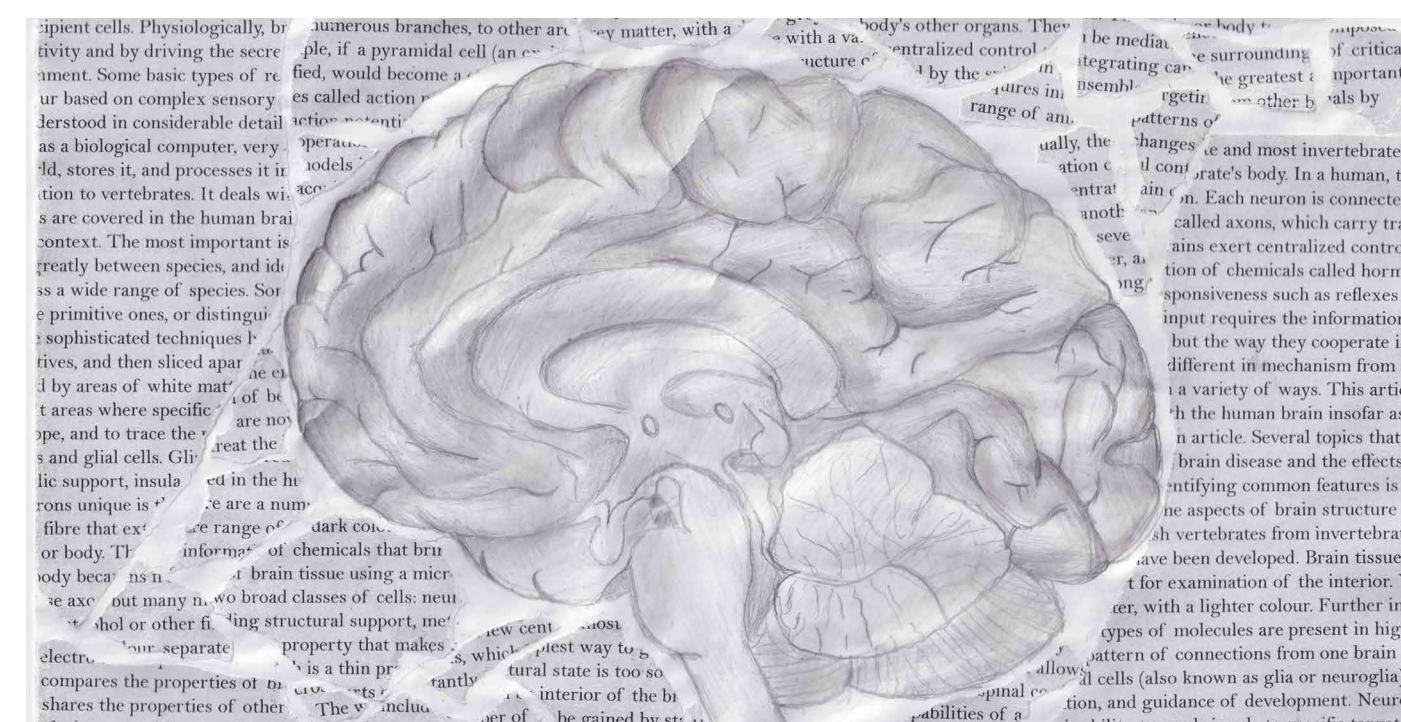
Drawings were shortlisted by a panel of judges and then Centre staff and students voted for their favourite artworks.

All winners received a digital voucher to spend at Angus & Robertson's online store, with each winner's school receiving a Modern Teaching Aids voucher to purchase additional educational resources.

Beyond the vouchers and prizes, the 1st place winners were offered an online award presentation by Centre researchers via Zoom before delivering an age-appropriate interactive educational lesson about the brain to the winner's class.



Cat 3 1st place, Jade A







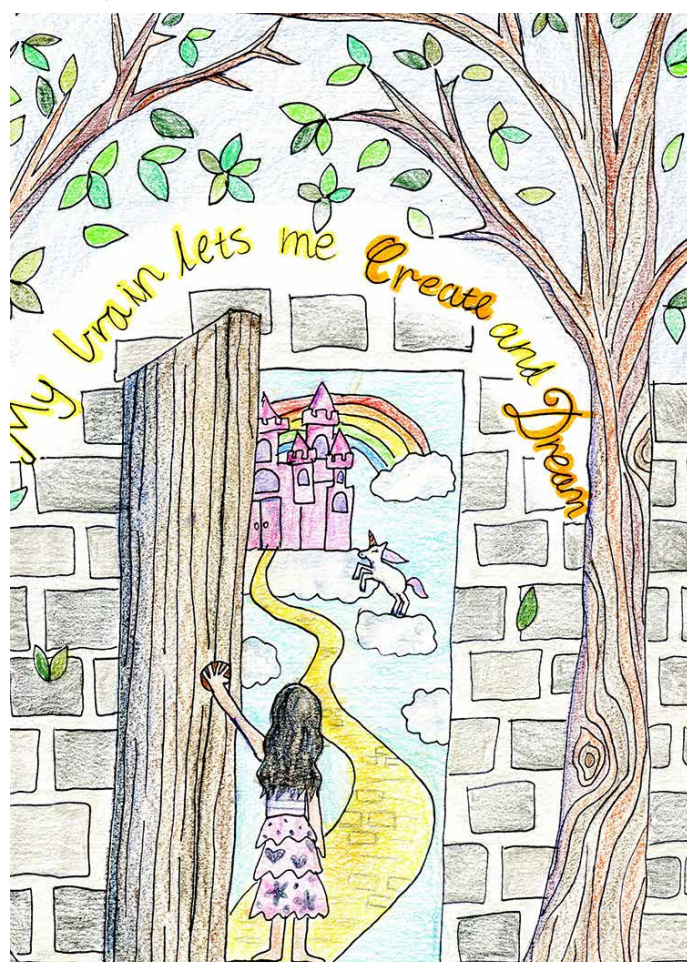
Cat 1 1st place, Billie W



Cat 2 3rd place, Selini G



Cat 2 1st place, Ethan D

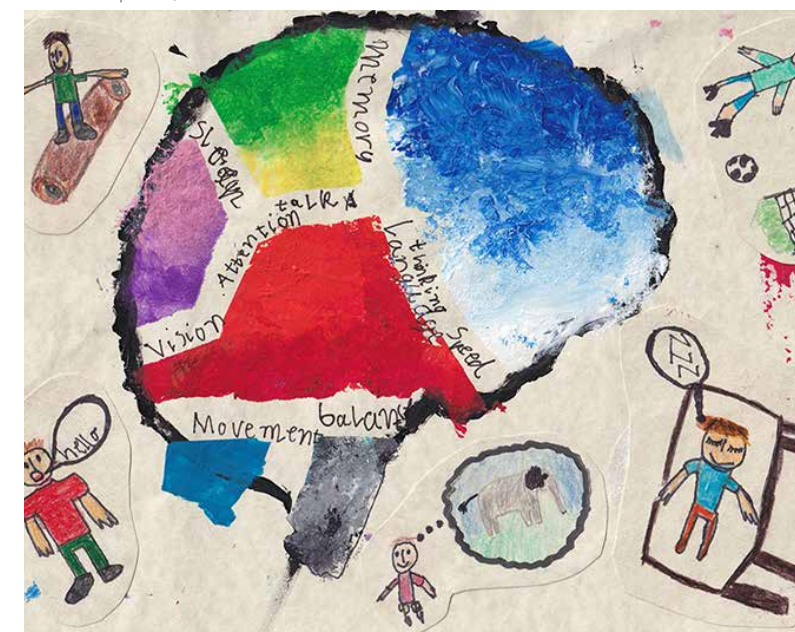


Cat 2 2nd place, Alana C

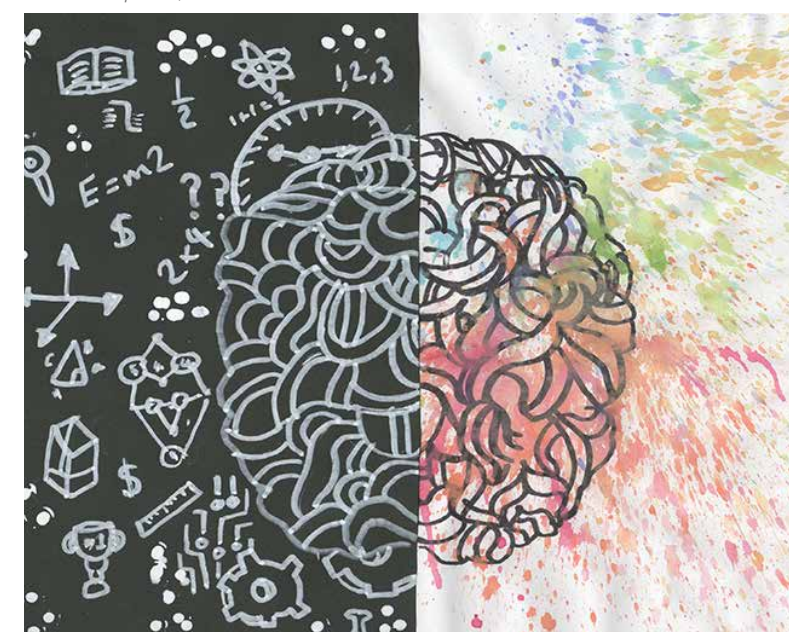
Why do I love my brain?  
"My brain helps me be  
happy and amazing".



Cat 1 3rd place, Jonah S



Cat 1 2nd place, Emilio M



Cat 3 2nd place, Constance K



# The Brain Dialogue - connecting communities and sharing knowledge

The Brain Dialogue is a neuroscience 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 the public.

## We engage with



**THE AUSTRALIAN PUBLIC**

We keep them abreast of the rapid progress in brain research and the issues and opportunities it offers.



**INVESTIGATORS**

They benefit from learning about research outside their field of interest.



**INDUSTRY**

They benefit from understanding the Centre's interests and capabilities.

## Plain language summaries

One major goal of the Brain Dialogue is to share Centre research publicly in a format that is easy to comprehend by the general public, ensuring everyone can access and understand our findings. Our Discovery section on the Brain Dialogue website presents Centre research 'In A Nutshell', summarises the next steps the researchers will undertake to further their investigations, and provides a link to the published research paper. The Brain Dialogue informs the broader community about the Centre's activities and also opens up opportunities for interdisciplinary research and linkage within the scientific community and industry.

In 2020, communication of the Centre's research successes via plain language summaries reflected the mature collaborations of the Centre's research program, with highlights featuring investigators from across all the research Themes of Cells and Synapses, Networks and Circuits, Brain Systems, and Models and Technologies. Featured research addressed the critical questions within integrative functions of attention, prediction and decision key to the Centre's mission, and featured true multi-node collaboration across Centre nodes.

In 2020, we wrote and published a record number of 27 plain language summaries which were shared across all the Centre's social media platforms. This significantly increased the reach of our findings and also increased the researchers' Altmetrics, leading to additional republication through social media channels, and additional media outlets.

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, meaning anyone can adapt and reuse the content, including for commercial purposes.

## 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, Twitter and LinkedIn accounts provide followers with curated content about new discoveries in brain research from the Centre and other relevant and reputable scientific sources. With a combined following of over 4000 users, our content was viewed 217,000 times throughout 2020.

The success of the Centre's social media knowledge sharing strategy can be seen with the increased Altmetrics scores of all published research, averaging 19.88, with 13 articles being ranked in the top 5% of all research outputs to be scored by Altmetric in 2020.

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.



## Connect with us

Website: [www.cibf.edu.au](http://www.cibf.edu.au)

Twitter: [@BrainDialogue](https://twitter.com/BrainDialogue)

Facebook: [/BrainDialogue](https://www.facebook.com/BrainDialogue)





## End-users' views on experimental trials of a novel cortical implant

Brain computer interfaces (BCIs) are an innovative technology that involve the surgical insertion of an experimental technology. The Centre has recently conducted a study on the perspectives of potential end-users of a unique cortical implant that has the potential to provide new treatments for previously intractable conditions, such as vision impairment, treatment resistant epilepsy, and spinal cord injury. The study was conducted in collaboration with the Monash Vision Group who developed the world leading brain computer interface (BCI) that is soon to be trialed in a bionic vision system. BCIs also raise some significant ethical and clinical challenges that need to be addressed, including the ability to obtain informed consent from patients desperate for a cure and the potential for the device to radically affect an individual's agency, identity, and independence in ways that are difficult to anticipate.

In this study, a total of 14 participants with epilepsy or a vision impairment participated in a number of focus groups (via Zoom due to COVID-19) to obtain valuable insights into their own ethical concerns about the future trials of the device, views on the device design and the necessary functional improvement they would require before agreeing to participate in a trial. Specifically, the aim of the study was to:

1. Explore the interests of potential end-users in the use of emerging BCIs
2. Examine the hopes, concerns and expectations that potential end users have regarding BCIs and their willingness to participate in trials of an experimental technology
3. Identify the factors that may influence their willingness to employ a BCI (e.g. intrusion of the device, usability, design, aesthetics, visibility) and the outcomes individuals are looking for from BCIs (e.g. impact to sight, quality of life, mobility, agency), and
4. Understand potential patient-led barriers to the commercialisation of BCIs and any ethical concerns that they have about participating in a trial of a BCI.

The data generated from this study provides crucial guidance for the ethical development of BCIs generally, and may influence how conditions such as vision impairments and epilepsy are experienced in the future.

Preliminary findings demonstrate that it is crucial for end-users to be intimately involved in all stages of the clinical device design if the device is to match end-user needs and be compatible with their lifestyles. Most participants were very interested in the potential of the implant, but had a number of practical concerns that would need to be addressed before they would have a BCI implanted. Clear communication with potential end-users will be critical for the successful trial and innovation of this cutting-edge technology.

2020 was a particularly challenging year for the Neuroethics Program, the main activities of which are to engage with community about the ethical and social issues raised by neuroscience through public events and other engagement activities, and provide avenues for researchers in the field to come together.

Despite these challenges, the Neuroethics Program has created new inroads in community engagement and reached its widest audience to date.



## 'I Am Human' film screening and panel discussion

As researchers develop new brain implants that can restore and enhance human function in ways that were not possible previously, society is being forced to consider what it means to be human. Will the brain technologies used today in medicine eventually lead to super human abilities or to a revolution of our sense of self? To explore these questions raised by advances in brain science, Centre Neuroethics Program Coordinator A/ Professor Adrian Carter, with support of the IEEE Brain and the International Neuroethics Society, organised a virtual film screening and panel discussion looking at the feature documentary 'I am Human', which premiered at the 2019 Tribeca Film Festival. The film explores the co-evolution of humans and technology by following three subjects with implantable brain interfaces and the ethical implications of this technology on society. A panel of experts met on 2 December 2020 to discuss various technological and ethical issues raised in the film and address questions submitted by participants. Panelists included:

- » Nita Farahany, Duke Law School – Leading scholar on the ethical, legal, and social implications of biosciences and emerging technologies, and who appears in the documentary
- » Jennifer French, Neurotech Network – An accomplished athlete, writer, and speaker who organises patient engagement initiatives and advises corporations and non-for-profit organisations working in the neurotechnology industry
- » Jacob Robinson, Rice University – Innovative researcher who uses nanofabrication technology to create miniature devices that manipulate and monitor neural circuit activity
- » Joseph J. Fins, Weill Cornell Medical College – Leading scholar and clinician with a focus on the ethical and policy issues related to brain injury and disorders of consciousness, who was the moderator for this panel discussion.

The event was attended by over 600 participants, the largest audience that we have reached so far, and included over 200 engineers. The virtual platform has greatly increased our ability to reach a larger and broader audience. However, we look forward to welcoming everyone in person at venues across Australia in 2021.

## International Neuroethics Conference

Unfortunately, we were unable to hold our annual Neuroscience and Society Conference in Australia this year; the first time in five years. However, for the first time in its history, the International Neuroethics Society (INS) Meeting, the peak event in the field, was held completely online, providing an opportunity for Australian academics and practitioners to engage with a wider

audience on an international stage from the comfort of their office or lounge room. A/Professor Adrian Carter chaired the program committee for the meeting. The INS annual meeting brings together diverse global perspectives and voices from academia, industry, health care, regulators, law experts, and people with lived experience that are needed to tackle global challenges at the intersection of ethics, law, philosophy and neuroscience.

The program for the 2020 meeting centered on the theme 'Our Digital Future: Building Networks Across Neuroscience, Technology and Ethics' and addressed many areas in which technologies and data concerning the brain are developed, deployed, utilised and regulated.

Digital technologies, including advanced computing and artificial intelligence, are rapidly reshaping the field of neuroscience. Major societal shifts are also radically transforming research and innovation. For example, the COVID-19 global pandemic has fast-tracked the use of digital technology to monitor and manage health and wellbeing. The extraordinary surge in awareness of social and historical injustice and inequality, as evidenced by global support for the Black Lives Matter movement, is leading to renewed efforts to address implicit and explicit hierarchies that allocate social value, agency, power, and concrete resources in ways that reinforce and justify those hierarchies.

The locus of neuro-innovation has also shifted, as major data giants like Google, Facebook and Apple, and high-profile start-ups such as Neuralink and Kernel, have taken a dominant role in driving the development of emerging technologies. The increasing ability to capture brain data, as well as industry's expanded role in neurotechnologies, are providing new opportunities for scientific discovery, but also challenges for governance, data privacy and ownership, and justice.

This was the largest meeting ever held in the field of neuroethics, reaching over 600 registrants from over 30 countries. The 2021 meeting will also be held online, providing greater opportunity for collaboration and engagement.

## A global program in public engagement about neuroscience

For the past four years, the Global Neuroethics Summit (GNS), the working group for the International Brain Initiative, has been holding workshops to foster international collaboration on the ethical and social issues raised by neuroscience. Previous meetings have been held in Shanghai, Daegu, Seoul and Stockholm. In 2020 the GNS held a virtual meeting to discuss international efforts to promote public engagement with neuroscience and its impact on society. The meeting was attended by a number of Australian representatives from the Centre and the Australian Brain Alliance. A comprehensive review of international efforts was tabled at the meeting, which highlighted The Brain Dialogue as a leader in public engagement about neuroscience globally. The results of this meeting are due to be published in early 2021.



## Neuroinformatics

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. Centre members are represented on the INCF Governing Board (voting Deputy Chair), Council for Training, Science and Infrastructure (2 voting members), Standards and Best Practices Committee (member) and Infrastructure Committee (Chair).

As the INCF Australian node, the Centre works with Australian eResearch organisations, including MASSIVE, Australia's specialised high-performance computing facility for imaging and visualisation, to provide neuroinformatics research services to Australian neuroscientists. Neuroscience has grown to become the largest user community on MASSIVE, a result of the partnership with the Centre, with projects across multiple Centre nodes using the resource for data processing and modelling.

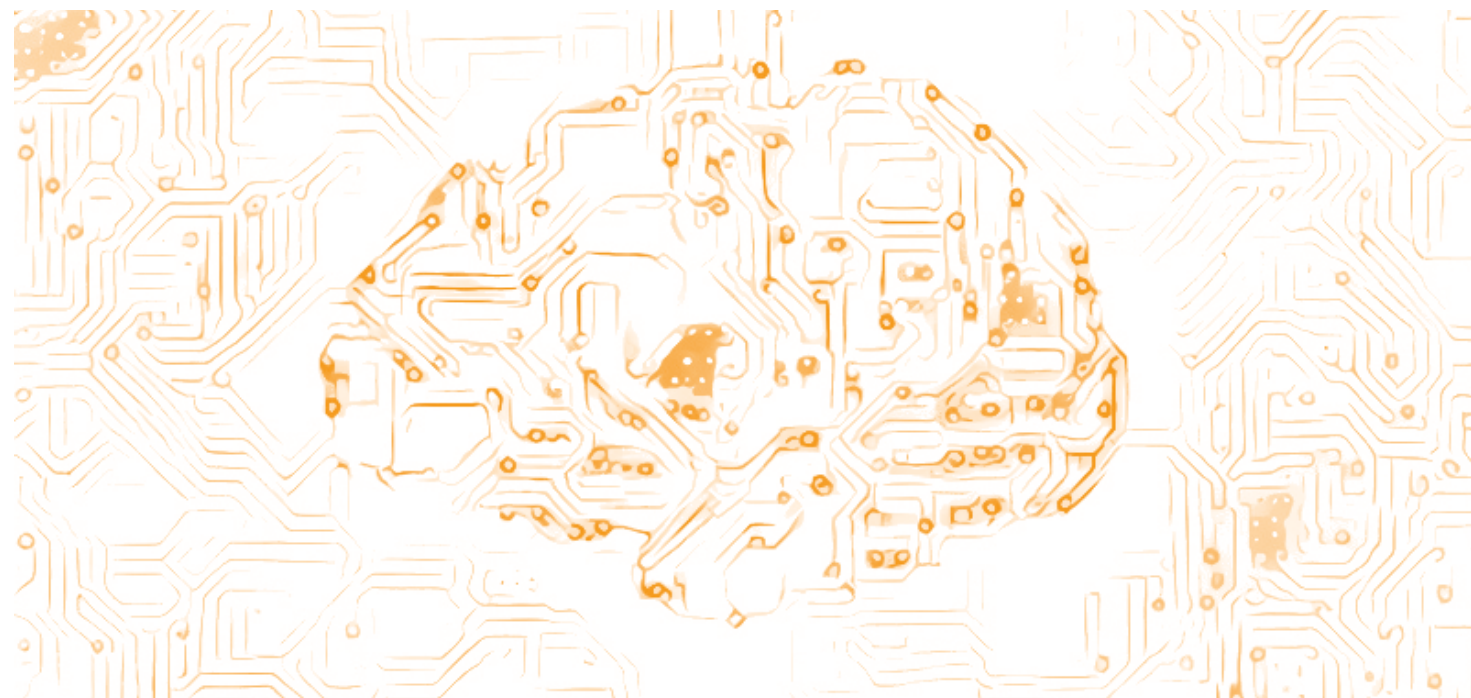
As the INCF Australian node the Centre represents Australian neuroinformatics efforts and promotes and prioritize neuroinformatics on a national scale, including working on the development of tools and best practice for the storage, sharing and publishing of imaging data. The Australian node works with INCF globally to foster scientific collaboration, advancing training and coordinate the global development of neuroinformatics.

Centre Neuroinformatics coordinator Professor Wojtek Goscinski is Primary Chief Investigator on the Monash University-led three-year Australian Characterisation Commons at Scale (ACCS) project, funded by the Australian Research Data Commons and in partnership with ten universities. The ACCS will deploy

a Characterisation Commons (CC) for thousands of researchers who use characterisation techniques, facility scientists who run instruments, and researchers using imaging collections, and will uplift the research capability offered to industry. The outcome will be a rich ecosystem of computing systems, data repositories, workflows, and services, connected with instruments. It will coordinate the implementation of persistent identifiers (PIDs), schemas, and formats to manage findable, accessible, interoperable, and reusable (FAIR) data. And it will run a national training and outreach program that will both develop content and work in partnership with centres of excellence. The CC will underpin techniques including electron (EM) and light microscopy, magnetic resonance imaging (MRI), magnetoencephalography (MEG), electroencephalography (EEG), positron emission tomography (PET), X-ray CT, nuclear and synchrotron techniques, cytometry, secondary-ion mass spectrometry, X-ray diffraction, scattering techniques, and nuclear magnetic resonance (NMR).

As the Australian INCF node the Centre was to co-host (with the Allen Institute for Brain Science) the 2020 Neuroinformatics Assembly, which was planned for Seattle in August 2020. Centre members Prof Marcello Rosa, Professor Wojtek Goscinski and Dr Ben Fulcher were on the organising committee for the assembly, which unfortunately had to be cancelled due to COVID-19 pandemic restrictions. The 2021 Assembly will take place virtually, including participation from Australian INCF node representatives.

Centre Neuroinformatics coordinator Professor Wojtek Goscinski is Primary Chief Investigator in the Australian Characterisation Commons at Scale (ACCS) project, which will provide Characterisation Commons (CC) for thousands of researchers. The outcome will be a rich ecosystem of computing systems, data repositories, workflows, and services, connected with instruments.







## Equity and diversity

The Centre's Gender, Equity and Diversity Committee (GEDC) consists of volunteers from both outside and within the Centre, including Chief Investigators, Associate Investigators and early and mid-career researchers, who develop initiatives and formalise policies to improve gender balance, equity and diversity in the Centre.

During 2020, the Gender, Equity and Diversity Committee (GEDC) developed various initiatives to support CIBF members during the COVID-19 pandemic. As a result of Centre-wide survey feedback, the GEDC worked towards providing additional support above and beyond the scope of the committee to Centre members identified as most at risk of food/home/health security from reduced income due to COVID-related delays in their research.

Due to the suspension of most academic travel throughout the year, the need for travel-related caregiver support was significantly reduced. That being the case, these funds were reallocated to support Centre members with caregiving responsibilities who faced different challenges in 2020, including working from home while providing care, and for some the increased need to support elderly, immunosuppressed or disabled relatives. This caregiver grant intended to offset some of the out-of-pocket expenses incurred by caregivers during the COVID-19 pandemic.

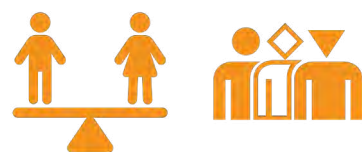
In addition to the caregiver grant, the GEDC developed a joint initiative with the ECR Executive Committee to fund a bridging fellowship program, providing financial assistance to Centre PhD students and post-doctoral fellows identified at risk of financial hardship due to COVID-related delays in their research.

Due to COVID-19, some Centre researchers experienced difficulty acquiring data or performing experiments, while other researchers suffered reduced staffing available to analyse previously acquired data. To combat these issues and help foster connections between Centre members and employment opportunities, the GEDC created an online space where researchers could submit or look for new research opportunities. This initiative not only connected individuals with potential employment opportunities, but also promoted additional cross-node collaboration.

In addition to COVID-19 initiatives, the GEDC expanded on their 2019 achievements of implementing a face-to-face workshop on unconscious bias training, offering an E-learning course in diversity and inclusion from Psynapse Consultancy Services. This course included training on the reasons why diversity and inclusion are so important to business performance; the key challenges to inclusion, including unconscious bias; awareness of how unconscious bias gets in the way of good decision-making. Offering such training online in addition to face-to-face, ensured every Centre member could benefit from accessing this training initiative if they wished to do so.

*The 2020 Committee comprised Dr Sharna Jamadar (VIC), Prof Michael Ibbotson (VIC), Dr Teri Furlong (NSW), Dr Ilvana Dzafic (VIC), Prof Nao Tsuchiya (VIC), Dr Nafiseh Atapour (VIC), and Ms Hatice Sarac (VIC).*

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



## Australian Brain Alliance

In 2020 a number of Centre Chief and Associate Investigators continued to have leadership roles in the Australian Brain Alliance (ABA), a consortium of research institutes, higher education providers, and business leaders in the brain science and technology industry.

Centre researchers, on behalf of the ABA, met with representatives from the office of the Minister for Industry, Science and Technology in Canberra in February 2020, to advocate to the federal government for major investment in the ABA proposal for an Australian Brain Initiative. The COVID-19 pandemic however meant the ABA was unable to proceed with its plans for further significant government advocacy activities in 2020. The ABA was thus unable to significantly build on the work undertaken in 2019 to build Australia's brain research projects and capabilities into a truly national endeavour with impact on a global scale.

The Centre however continued to provide administrative support in 2020 to the ABA Executive in its efforts to coordinate and build capacity in basic neuroscience and to further catalyse technological and scientific advances to sustain a thriving neurotechnology environment in Australia, and to engage global collaboration across industry and science. The support provided by the Centre was especially important in 2020 as the Australian Academy of Sciences advised that due to the economic impacts of the pandemic it would no longer be able to provide resources to support the ABA's activities.

In 2020 the Centre also supported the ABA as it represented the interests of the Australian brain research community as a founding member organisation of the International Brain Initiative, working alongside representatives of the large-scale international brain research programs of the United States, Japan, China, Europe, Korea and Canada.

We anticipate the Centre will work closely with the ABA to build on these advocacies and other activities further in 2021.



In 2020 the Centre supported the ABA as a founding member organisation of the International Brain Initiative, working alongside representatives from the United States, Japan, China, Europe, Korea and Canada.



# Personnel

## Chief Investigators

(click on image for full bios)



Gary Egan  
Director  
Monash University



Marcello Rosa  
Deputy Director  
Monash University



Jason Mattingley  
Associate Director  
University of Queensland



Ehsan Arabzadeh  
Chief Investigator  
Australian National University



Marta Garrido  
Chief Investigator  
University of Melbourne



Ulrike Grünert  
Chief Investigator  
University of Sydney



Michael Ibbotson  
Chief Investigator  
University of Melbourne



Arthur Lowery  
Chief Investigator  
Monash University



Paul Martin  
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



Pankaj Sah  
Chief Investigator  
University of Queensland



Stan Skafidas  
Chief Investigator  
University of Melbourne



Greg Stuart  
Chief Investigator  
Australian National University



Professor George Paxinos is a major contributor to the Centre's Brain Systems and Neural Circuits themes; he is the principal person investigating similarities and differences between brain structures in animals and humans.

Prof George Paxinos, AO  
*Chief Investigator*  
*University of New South Wales*

Prof George Paxinos completed his BA at The University of California at Berkeley, his PhD at McGill University, and spent a postdoctoral year at Yale University. He and Charles Watson are the authors of The Rat Brain in Stereotaxic Coordinates. With over 50,000 citations across its 7 Editions (March 2014), it is the third most cited book in science after Molecular Cloning and the Diagnostic and Statistical Manual of Mental Disorders. Prof Paxinos has also published another 45 books on the structure of the brain of humans and experimental animals, his most recent being MRI/DTI Atlas of the Rat Brain. His book Atlas of the Human Brainstem (co-authored by Centre Fellow Teri Furlong and AI Charles Watson) was a finalist in the 2020 Prose awards, nominated by the Association of American Publishers for excellence in the category of biological and life science.

His work has been recognised by an AO, Ramaciotti Medal, Humboldt Prize, a \$4 million NHMRC Australia Fellowship and the NSW Premier's Prize for Excellence in Medical Biological Sciences in 2015. He is a Fellow of the Australian Academy of Science, the Academy of Social Sciences in Australia and a corresponding member of the Academy of Athens.

In 2020 he was offered an appointment as a Distinguished Fellow of the Royal Society, in recognition of his work on brain mapping resultant from his Centre research.



Management and administration

- » Glenn Papworth, Centre Manager (Monash University)
- » Jessica Despard, Senior Officer (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 New South Wales)
- » Cindy Guy, Node Administrator (University of Sydney)
- » Roxanne Jemison, Node Administrator (University of Queensland)
- » Tenille Ryan, Node Administrator (University of Melbourne)
- » Danielle Helmers, Node Administrator (Australian National University)

Program coordinators

- » Adrian Carter  
Neuroethics Coordinator (Monash University)
- » Sharna Jamadar  
Chair, Gender, Equity & Diversity Committee (Monash University)
- » Pulin Gong  
Neuroinformatics and Computational Resources Coordinator (University of Sydney)
- » Wojtek Goscinski  
Neuroinformatics and Computational Resources Coordinator (Monash University)

Partner investigators

- » Matthew Diamond, International School for Advanced Studies, Italy
- » 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
- » Nicholas Price, Monash University
- » Ramesh Rajan, Monash University
- » Fabio Ramos, University of Sydney
- » Olaf Sporns, Indiana University, USA
- » Nao Tsuchiya, Monash University
- » Trichur Vidsyagar, University of Melbourne
- » Charles Watson, Curtin University

Centre Fellows

- » Tahereh Babaie, University of Sydney
- » Madhusoothanan Bhagavathi Perumal, University of Queensland
- » Robin Broersen, Australian National University
- » Oliver Cliff, University of Sydney
- » Calvin Eiber, University of Sydney
- » Timothy Feleppa, Monash University
- » Teri Furlong, University of New South Wales
- » Natasha Gabay, University of Sydney
- » Saba Gharaei, Australian National University
- » Sharna Jamadar, Monash University
- » Tim Karle, University of Melbourne
- » Steve Kassem, University of New South Wales
- » Ehsan Kheradpezhoh, Australian National University
- » Sammy Lee, University of Sydney
- » Chin-Hsuan (Sophie) Lin, University of Melbourne
- » Rania Masri, University of Sydney
- » Anand Mohan, Monash University
- » Christopher Nolan, University of Queensland
- » David Painter, University of Queensland
- » Alexander Pietersen, University of Sydney
- » Roger Marek, University of Queensland
- » Shane Tonnisen, University of Melbourne
- » Cong Wang, University of Queensland
- » Massoud Yajadda, University of Sydney
- » Dongping Yang, University of Sydney
- » Molis Yunzab, University of Melbourne

Centre Scholars

- » Elissa Belluccini, University of Sydney
- » Guozhang Chen, University of Sydney
- » Guthrie Dyce, Australian National University
- » Suraj Honnuraiah, Australian National University
- » Young Jun (Jason) Jung, University of Melbourne
- » Thomas Lacy, University of Sydney
- » Tianzhi Li, University of Melbourne
- » Lucinda Lilley, University of Sydney
- » Yuxi Liu, University of Sydney
- » Xiaochen Liu, University of Sydney
- » Xian Long, University of Sydney
- » Daniel Naomenko, University of Sydney
- » Subha Nasir-Ahmad, University of Sydney
- » Shencong Ni, University of Sydney
- » Edwina Orchard, Monash University
- » Lachlan Owensby, Australian National University
- » Kevin Qu, University of Sydney
- » Angela Renton, University of Queensland
- » Jordan Sibberas, University of Melbourne
- » Taylor Singh, Australian National University
- » Christodoulos Skilos, University of New South Wales
- » Felix Thomas, Australian National University
- » Nasir Uddin, University of Sydney
- » Cong Wang, University of Queensland
- » Asem Wardak, University of Sydney
- » Yang Yu, University of Melbourne

Honours Students

- » Lauren Addamo, University of Melbourne
- » Alyssa Baldicano, University of Sydney
- » Micaela Dear, University of Queensland
- » Dana Galligan, University of Queensland
- » Lachlan Gorey, University of Sydney
- » Joshua Kugel, University of Melbourne
- » Ivan Ma, University of Sydney
- » Alexander McInnes, University of Sydney
- » Eloisa Perez-Bennetts, University of Sydney
- » Pok Him Siu, University of Sydney
- » Kurt Vanstone, University of Sydney
- » Ben Xu, University of Sydney
- » Sera Yoo, University of Queensland

Professional Staff

- » Shi Bai, Monash University
- » Alyssa Baldicano, University of Sydney
- » Arzu Demir, University of Sydney
- » Brendon Harris, University of Sydney
- » Daria Malmanova, Monash University
- » Subha Nasir-Ahmad, University of Sydney
- » Mario Novelli, University of Sydney

Dr Tahereh Tekieh  
*Affiliate Fellow*  
*University of Sydney*



Tahereh completed her PhD in Computational Physics at Institute for Research in Fundamental Sciences (IPM), Tehran, Iran in 2016 and moved to Australia to complete three and a half years of postdoctoral research with Professor Peter Robinson and Dr. Svetlana Postnova.

During this time, she extended the “Model of Arousal Dynamics” which is a quantitative model to predict sleep times, circadian phase, melatonin level, and alertness. Now the model accounts for the effects of light spectrum, timing, and irradiance based on the non-visual processes that regulate physiology and behaviour of humans. This model is the only model to date that accounts for the dynamic effects under different light sources with applications ranging from architectural lighting design to light therapy interventions. The model can be deployed to be widely used in the real world specially where the circadian clock is disrupted by the changes in light exposure time as in jet lag and shift work. This ground-breaking research has been published in the *Journal of Pineal Research* (IF 15.221), which is ranked amongst the top 10 journals in the field of endocrinology.

She has also recently joined the organisation *She Loves Data* as a volunteer, to use her highly transferable skills achieved in academia to support women from diverse backgrounds to pursue careers in data and technology.



Affiliate Fellows

- » Mehdi Adibi, Monash University
- » Ali Almasi, University of Melbourne
- » Nafiseh Atapour, Monash University
- » Claire Bradley, University of Queensland
- » Alexander Bryson, University of Melbourne
- » Tristan Chaplin, Monash University
- » Nela Durisic, University of Queensland
- » Ilvana Dzafic, University of Melbourne
- » Amu Faiz, University of Queensland
- » Daniel Fehring, Monash University
- » Hannah Filmer, University of Queensland
- » Kelly Garner, University of Queensland
- » Maureen Hagan, Monash University
- » Anthony Harris, University of Queensland
- » Will Harrison, University of Queensland
- » James Henderson, University of Sydney
- » Cliff Kerr, University of Sydney
- » Marcin Kielar, University of Queensland
- » Conrad Lee, Australian National University
- » Delphine Levy-Bencheton, University of Queensland
- » Snezana Maljevic, University of Melbourne
- » Sam Merlin, University of Western Sydney
- » John Morris, University of Queensland
- » Eli Muller, University of Sydney
- » Brandon Munn, University of Sydney
- » Lei Qian, University of Queensland
- » Dragan Rangelov, University of Queensland
- » Kay Richards, University of Melbourne
- » Margreet Ridder, University of Queensland
- » Robert Sullivan, University of Queensland
- » Shi (Scott) Sun, University of Melbourne
- » Yajie Sun, University of Queensland
- » Matthew Tang, Australian National University
- » Angelo Tedoldi, University of Queensland
- » Tahereh Tekieh, University of Sydney
- » Wei Tong, University of Melbourne
- » Elizabeth Zavitz, Monash University

Affiliate Scholars

- » Emily A-Izzeddin, University of Queensland
- » Tim Allison-Walker, Monash University
- » Talina Bayeleva, University of Melbourne
- » Zhijian Cai, Monash University
- » Jonathan Chan, Monash University
- » India Cowie-Kent, Monash University
- » Yadeesha Deerasooriya, University of Melbourne
- » Amu Faiz, University of Queensland
- » Pippa Iva, Monash University
- » Linghan Jia, University of Melbourne
- » Shivam Kalhan, University of Melbourne
- » Matthew Kenna, University of Queensland
- » Caixia Lin, University of Queensland
- » Sylvie Loneragan, University of Queensland
- » Jamie McFadyen, Monash University
- » Morgan McIntyre, University of Queensland
- » Samra Naz, University of Queensland
- » Gratia Nguyen, University of Sydney
- » Brian Oakley, Monash University
- » Roshini Randeniya, University of Queensland
- » Najmeh Sajedianfard, University of Sydney
- » Blake Saurels, University of Queensland
- » Cooper Smout, University of Queensland
- » Imogen Stead, University of Queensland
- » Parnayan Syed, University of Queensland
- » Rebecca West, University of Queensland

Affiliate professional staff

- » Rebecca Bhola, Monash University
- » Cecilia Cranfield, Monash University
- » Shuang Jiang, Australian National University
- » David Lloyd, University of Queensland
- » Benjamin Mitchel, Australian National University
- » Ana Morello, Australian National University
- » Abbey Nydam, University of Queensland
- » Kelly O'Sullivan, Monash University
- » Petra Sedlak, University of Queensland
- » Jeremy Taylor, University of Melbourne
- » Katrina Worthy, Monash University
- » Li Xu, University of Queensland

Dr Dragan Rangelov  
*Senior Research Fellow*  
*University of Queensland*



Dragan obtained his PhD in Systemic Neurosciences from the Ludwig-Maximilians University Munich, Germany under supervision of Professor Hermann Mueller, Chair of General and Experimental Psychology. In Munich, he specialised in cognitive neuroscience of visual attention and cognitive control. Thereafter, Dragan continued his studies of cognitive control as a principal investigator on a project funded by the German Research Foundation. In 2016, he joined the cognitive neuroscience lab at the University of Queensland.

Together with Professor Jason Mattingley, he developed a research program focusing

on the interplay between visual attention and decision making. In his work, he uses computational modelling of behaviour and neuroimaging data to characterise how the brain integrates several sources of sensory input in support of a single, integrated decision. In 2020, this research led to a publication in *NeuroImage* and a successful NHMRC Ideas grant which will investigate integrated decision-making across lifespan, with an emphasis on stroke survivors. Also in 2020, Dragan was successful in obtaining funding from the Department of Science and Technology Research Network for Undersea Decision Superiority. This project will develop a neurofeedback training protocol aiming to improve decision making and inform selection and training protocols of submarine operators. A new collaborative network of researchers from Monash University (Professor Mark Bellgrove) and the University of Melbourne (Professor Stefan Bode) will join the UQ team.

Next, Dragan will focus on translating his findings in healthy humans to animal models. In 2020, he has established a collaborative network with experts in primate electrophysiology from Monash University (Dr Yan Tat Wong and Dr Maureen Ann Hagan) and RMIT University (Dr Shaun Cloherty). This research will characterise effects of prediction violation on sensory coding of visual inputs. Most interestingly, his work in humans has shown that prediction violations in auditory modality affect processing of an unrelated visual input. The collaboration with electrophysiologists will identify the neural circuits that support cross-modal effects of prediction violation.

Dragan's research focusses on integrated decision-making across the lifespan with an emphasis on stroke survivors.


Dr Maureen Hagan  
*ARC DECRA Fellow*  
*Monash University*

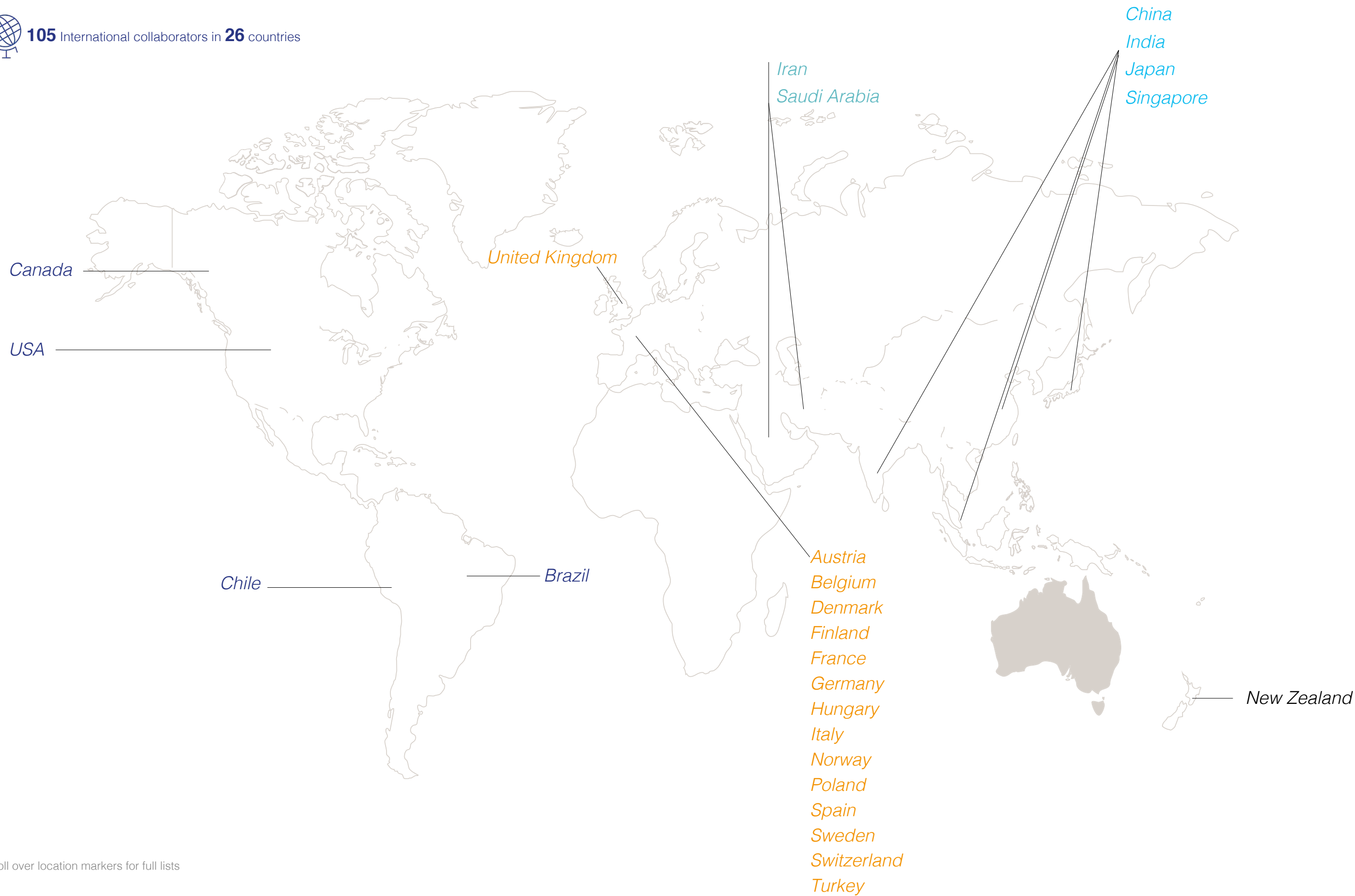
Maureen Hagan is a research fellow in the department of Physiology at Monash University. She completed her undergraduate degree at the University of California, Los Angeles followed by a doctoral degree in neural science at New York University. She moved to Monash University in 2014 to complete her postdoctoral training. In 2018 she received an ARC DECRA fellowship to foster her transition to an independent research program. Her work has been recognized with a Young Investigator Award from the international Marmoset Bioscience community.

Her research focuses on the mechanisms of neuronal communication both within and across brain areas. Specifically, how the laminar architecture of cortex organizes and integrates information from feedforward and feedback processes. Her work is multidisciplinary and includes high-density, multi-brain area electrophysiology, computational neural models, neural engineering, and behavioral models of sensorimotor integration and cognition.





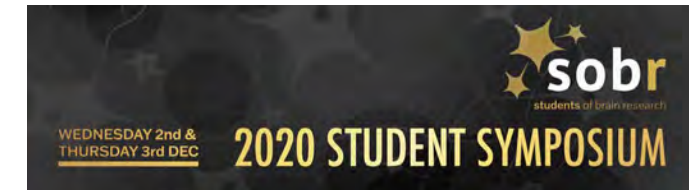
 **105** International collaborators in **26** countries



 Roll over location markers for full lists



# Events



## 2020 Students of Brain Research (SOBR) 10th annual symposium

The 2020 SOBR Student Symposium was held on the 2 and 3 December 2020. Due to the restrictions imposed as a result of the global pandemic, this year's student symposium was held virtually via Zoom. Overall, 113 people registered from a wide range of institutions. Because of the nature of online symposia, attendees were able to join the meeting for sessions of particular interest to them with approximately 40 people in attendance at each session at all times throughout the two days of the Symposium.

A lot of positive feedback was received regarding the professional quality of the symposium and the calibre of the student presentations. With the number of talented and driven researchers that presented at the Symposium, it was clear that the SOBR members across Victoria and Australia are conducting impactful research. The SOBR Symposium gives neuroscience and brain research students from across Australia an opportunity to present their research amongst peers in an engaging and supportive environment, often for the first time. The Symposium allowed students to build on their communication skills; a vital skill for all scientific researchers and an important component of training as a research student. The Symposium also gave the opportunity for student attendees (presenting and non-presenting) to view the work of their peers from a diverse range of research fields. This exposure to interdisciplinary research allows students to consider their own research interests from new perspectives. Importantly, the event also provided an opportunity for students to network amongst their peers from across institutes and universities in Victoria and beyond, which may lead to collaborations with other researchers within the field.

The SOBR committee is grateful for the valued sponsorship and continued support provided by the CIBF. The sponsorship provided has and will continue to have a significant impact for SOBR as well as the individuals who presented and won the generous awards provided by CIBF.

## ANS2020 Conference and AGM

The ANS2020 Online Conference and AGM, held on 9 December 2020, was a great success. In lieu of the usual face-to-face meeting, the Australasian Neuroscience Society (ANS) came together over Zoom to share the latest in neuroscience research data. A total of 220 people registered for the conference, and each session was attended by >100 registrants. The annual general meeting was held immediately after the conference.

Scientific highlights included the Plenary presentation by Professor Kate Drummond, who reported on her translational, clinical research program. Prof Drummond has studied the quality of life of glioma patients after surgery, and has identified specific actionable changes that she is now implementing in her clinic, and evaluating their capacity to improve quality of life outcomes. Presentations by early career researchers, Drs Robyn Brown and Philip Ryan were both engaging and complimentary, detailing the circuits in our brain that are dysregulated by over-eating or respond to fluid intake. Registrants were able to engage with the speakers after each session by jumping into designated online discussion rooms, and ANS students showcased their talent by competing in a 3-minute thesis competition in the afternoon.

The Centre sponsorship was used to cover the costs of conference administration.



*The Centre was proud to sponsor the ANS Conference and AGM in 2020.*

## COVID-19 impact on events

Due to the restrictions in place throughout most of 2020, we had very limited opportunity to host our usual centre events. However, our dedicated committees ensured that Centre members had opportunities to connect via online symposiums and other virtual catch-ups.





Key performance indicators

Performance KPIs	Target	Actual	%
<b>Research Outputs – with Centre acknowledgement or inclusion as an author affiliation</b>			
Journal articles	40	70	175%
Books	0	2	200%
Book chapters	0	2	200%
Conference papers	3	0	0%
AV recordings	0	4	400%
<b>Publication Quality – with Centre acknowledgement or inclusion as an author affiliation</b>			
Citations (cumulative)	600	2000	285%
Average impact factor	4	6.76	169%
Average web views per article	1,000	2745	275%
Average Altmetric score	10	19.88	199%
<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 online in place of face-to-face)</i>			
<b>Number of workshops/conferences held/offered by the Centre</b>			
National science meeting	1	0	0%
International meeting/ workshop	1	0	0%
ECR workshop	1	0	0%
<b>Additional Researchers</b>			
Post-doctoral researchers	25	26	104%
Honours students	8	13	163%
PhD students	25	26	104%
Affiliate Investigators <i>(students and researchers contributing to Centre activities who do not receive Centre funding)</i>	90	110	122%
<b>Number of Postgraduate Completions</b>	16	11	69%
<b>Number of Honours Completions</b>	8	11	138%
<b>Number of Mentoring Programs offered by Centre</b>			
Centre induction program	2	0	0%
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	12	133%
<b>Number of new organisations collaborating with, or involved in the Centre</b>	5	9	180%
<b>Number of Gender, Equity and Diversity Workshops</b>			
Face-to-face	1	0	0%
Online <i>(All sessions were offered face-to-face, in place of online sessions)</i>	1	1	100%
<b>Number of Travel Grants Given to Primary Caregivers</b>	5	0	0%
<b>End User Impact</b>			
Public lectures / events	2	0	0%
Primary & secondary education programs	3	2	67%
Brain Dialogue reach (number of web hits)	20,000	39,320	197%
Media – articles	15	673	4487%
Media – invited expert commentary	10	10	100%
<b>National / International Awards</b>	10	14	140%
<b>Accessibility of Research</b>			
Analysis tools available to Centre researchers / public	2	8	400%
Datasets available to Centre researchers / public	2	8	400%
<b>Integrative Research</b>			
Number of research outputs with authors from more than one group	30	38	127%
Number of interdisciplinary research programs	12	18	150%
<b>International Profile</b>			
Number of international visitors	10	11	110%
Number of international presentations	25	23	92%
Number of visits to overseas laboratories	16	8	50%



Financial statement

	2014	2015	2016	2017	2018	2019	2020
	\$	\$	\$	\$	\$	\$	\$
FUNDS CARRIED FORWARD FROM PREVIOUS YEAR	-	2,741,132	3,323,469	3,352,518	2,748,592	2,445,345	2,669,335
Adjustment to carry forward from previous years			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	3,256,463
Australian National University cash contribution	111,324	111,324	111,124	111,324	111,324	111,324	111,324
Monash University cash contribution	318,434	318,434	371,625	318,795	318,795	318,795	318,795
University of New South Wales cash contribution	-	4,445	148,002	49,334	49,334	44,890	49,334
University of Queensland cash contribution	120,390	206,800	120,390	154,370	160,520	193,962	167,209
University of Melbourne cash contribution	153,706	155,579	146,444	162,839	154,642	188,921	148,344
University of Sydney cash contribution	132,711	241,810	153,706	186,745	153,706	153,706	120,667
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	25,000
Queensland Institute of Medical Research (QIMR) Berghofer cash contribution	-	-	42,028	31,698	24,343	26,827	29,373
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	6,895,844
EXPENDITURE							
Personnel	657,528	1,892,966	2,585,168	2,822,705	3,152,543	2,798,945	3,084,562
Consultants	21,287	392,266	352,984	414,111	230,976	224,117	36,796
Scholarships & support	28,274	115,058	37,517	112,961	136,016	94,459	155,909
Purchased Equipment	35,517	132,753	147,279	259,461	39,409	59,929	269,100
Lease / Hired Equipment	4,163	65,607	4,583	15,903	3,437	16,470	6,954
Maintenance (IT and lab)	429	78,640	2,889	77,864	14,435	13,535	29,238
Research Materials / Experiments	107,769	304,054	172,246	240,924	218,983	188,313	278,140
Travel and conferences	102,608	319,067	275,872	345,879	273,676	328,058	66,476
Sponsorships - scientific workshops & conferences	4,500	10,429	11,000	20,845	20,891	23,045	17,485
Non-research Initiatives	80,217	151,752	259,710	134,553	130,257	75,714	21,727
INCF Subscription	-	-	339,905	311,643	332,890	83,792	39,545
Other Expenditure	4,730	22,727	175,552	49,412	145,994	133,807	109,830
TOTAL EXPENDITURE	1,047,022	3,485,319	4,364,705	4,806,261	4,699,508	4,040,187	4,115,762
BALANCE CARRIED FORWARD TO FUTURE YEARS	2,741,132	3,325,445	3,352,518	2,748,592	2,445,345	2,669,335	2,780,081

In kind contributions

ADMINISTERING AND COLLABORATING ORGANISATION CONTRIBUTIONS	\$
Monash University	746,225
The Australian National University	322,542
University of New South Wales	107,000
University of Melbourne	288,102
University of Sydney	346,397
University of Queensland	359,778
TOTAL	2,170,044
PARTNER ORGANISATION CONTRIBUTIONS	
Cold Spring Harbor Laboratory	12,500
Duke University	25,000
International School for Advanced Studies	12,500
Karolinska Institute/INCF	57,741
National Institute for Health and Medical Research	12,500
National Institute of Mental Health	12,500
QIMR	38,316
Riken Center for Brain Science	12,500
Weill Cornell Medical College	17,278
TOTAL	200,835
TOTAL	2,370,879



## Additional funding

Grants awarded or active in 2020

### 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  
LE190100084  
\$898,450 (2019-2020)  
Centre Investigator: Gary Egan

Project Title: Electrophysiology platform for ion-channel characterisation  
LE200100190  
\$620,000 (2020)  
Centre Investigator: Steve Petrou

#### ARC Discovery Projects:

Project Title: Building a visual world: how brain circuits create and use representations  
DP210101042  
\$493,000 (2021-2024)  
Centre Investigators: Marcello Rosa, Elizabeth Zavitz, Yan Wong

Project Title: Biophysics-informed deep learning framework for magnetic resonance imaging  
DP210101863  
\$519,000 (2021-2024)  
Centre Investigator: Gary Egan

Project Title: Decoding neuronal populations for visually-guided decision and action  
DP210103865  
\$583,000 (2021-2024)  
Centre Investigators: Marcello Rosa, Shaun Cloherty

Project Title: Neurophysiological predictors of brain stimulation outcomes  
DP210101977  
\$558,000 (2021-2023)  
Centre Investigators: Paul Dux, Hannah Filmer, Jason Mattingley

Project Title: Diamond electrodes for bimodal cellular control  
DP210102750  
\$440,000 (2021-2023)  
Centre Investigator: Michael Ibbotson

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: 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

#### 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: Context matters: from sensory processing to decision making  
DE180100344  
DE200101468  
\$ 413,614 (2020-2021)  
Centre Investigator: Mehdi Adibi

**TOTAL ARC FUNDING**  
**\$12,821,463**

### OTHER

1	NHMRC Program Grant	\$15,000,000
1	NHMRC Development Grant	\$1,010,210
4	NHMRC Fellowships	\$2,160,768
18	NHMRC Project / Ideas Grants	\$15,433,420
6	Government Grants	\$8,746,707
7	International Grants	\$7,244,916
3	Industry / Philanthropic Grants	\$4,214,307
6	Institutional Grants	\$5,124,154

**TOTAL FUNDING FROM OTHER SOURCES**  
**\$58,934,482**

The above grants include allocations from 2013 onwards that were active in 2020.



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
BCI	Brain computer interfaces
BOLD	Blood oxygen level dependent
CI	Chief Investigator
CIBF	Centre for Integrative Brain Function
CoE	Centre of Excellence
COPE	Create Once, Publish Everywhere
DCM	Dynamic causal modelling
DECRA	Discovery Early Career Researcher Award
ECR	Early career researcher
EEG	Electroencephalography
EPFL	École polytechnique fédérale de Lausanne
FDG	Fluorodeoxyglucose
fMRI	Functional magnetic resonance imaging
GABA	gamma-aminobutyric acid
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
MRI	Magnetic resonance imaging
MT	Middle temporal visual area
NOR	Novel object recognition
PET	Positron emission tomography
PFC	Prefrontal cortex
PI	Partner Investigator
QBI	Queensland Brain Institute
QIMR	Queensland Institute of Medical Research
SISSA	Scuola Internazionale Superiore di Studi Avanzati
SOBR	Students of Brain Research
V1	Primary visual cortex

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