ANNUAL REPORT 2018

ARC CENTRE OF EXCELLENCE FOR INTEGRATIVE BRAIN FUNCTION

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

Understanding how
the brain interacts
with the world

ARC CoE FOR INTEGRATIVE BRAIN FUNCTION

Contents

Collaborating, Partner and Affiliate Organisations

Collaborating organisations

MONASH University

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

THE UNIVERSITY OF MELBOURNE

THE UNIVERSITY OF SYDNEY

Australian National University

UNSW AUSTRALIA

Partner organisations

QIMR Berghofer Medical Research Institute

CSH Cold Spring Harbor Laboratory

Weill Cornell Medicine

THE FRANCIS CRICK INSTITUTE

Duke UNIVERSITY

SISSA

NIH National Institute of Mental Health

NEW YORK UNIVERSITY

Human Brain Project
Unifying our understanding of the human brain

incf International Neuroinformatics Coordinating Facility

Institut de Neurosciences des Systèmes

RIKEN CBS Center for Brain Science

Affiliate organisations

Neuroscience Research Australia
Discover. Conquer. Cure.

NATIONAL VISION RESEARCH INSTITUTE OF AUSTRALIA

erc

Flinders UNIVERSITY

AUSTRALIAN COLLEGE OF OPTOMETRY

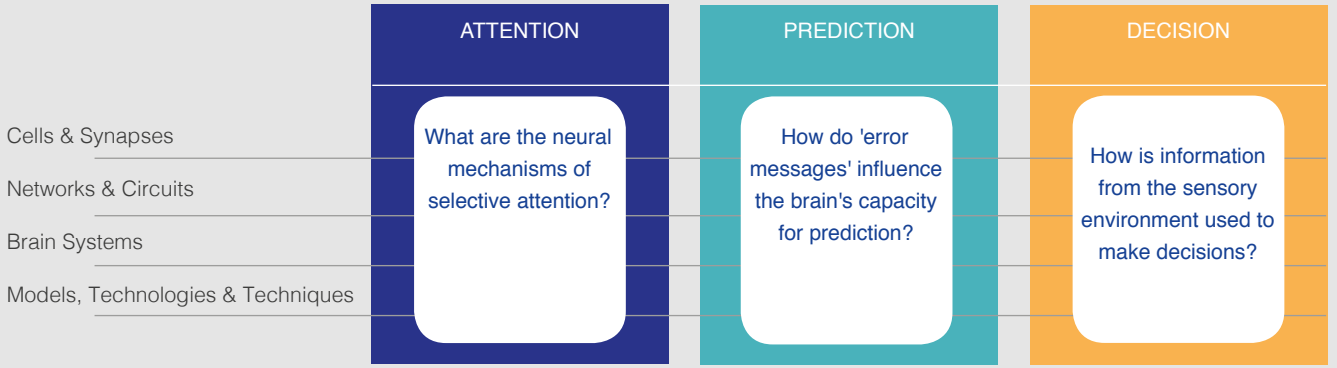
INTRODUCTION

Understanding how the brain interacts with the world is one of the greatest challenges of the 21st century. To address this challenge, brain researchers from around Australia, with expertise across multiple disciplines, have joined forces in the ARC Centre of Excellence for Integrative Brain Function (Brain Function CoE). The Centre has developed an integrated research program aimed at studying the brain across a multitude of spatial and temporal scales. By integrating research across scales and disciplines, the outcomes of the Centre will provide a more comprehensive understanding of how the brain functions as a whole.

To achieve these research goals, the Centre has focused research efforts on understanding how the brain integrates information at multiple scales - from nerve cell electrical and biochemical activity, through patterns of activity in large scale circuit networks to yield complex behaviour - in the three key integrative functions of attention, prediction, and decision. 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.

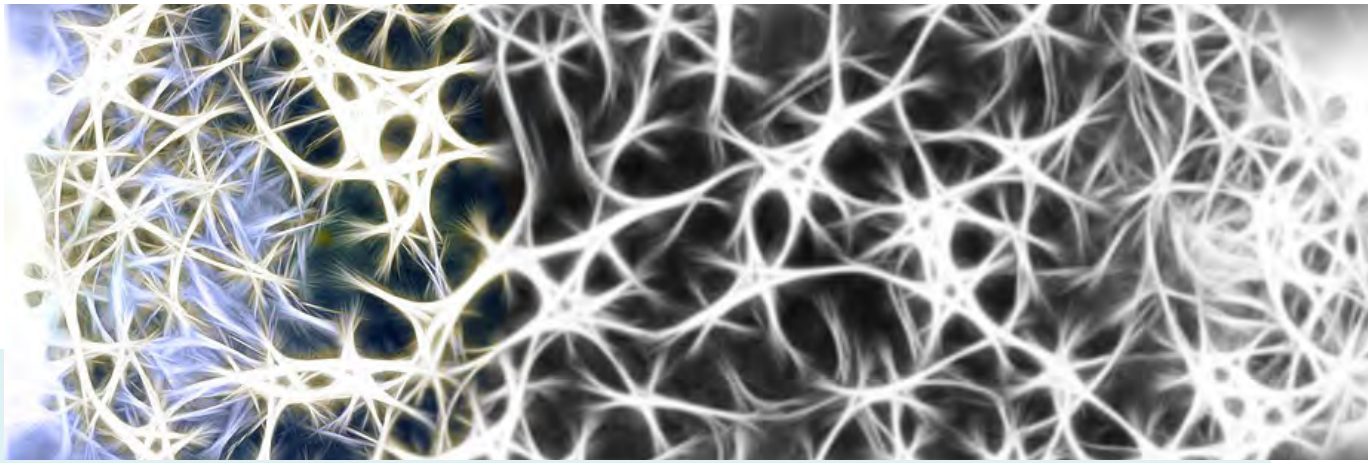
Developing outstanding early career researchers (ECRs) in the neurosciences is critical to Australia's international standing in science. The Centre is building internationally recognised excellence across the Australian neuroscience community by providing Centre ECRs with outstanding training and career 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 Australia wide 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.



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

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



Mission

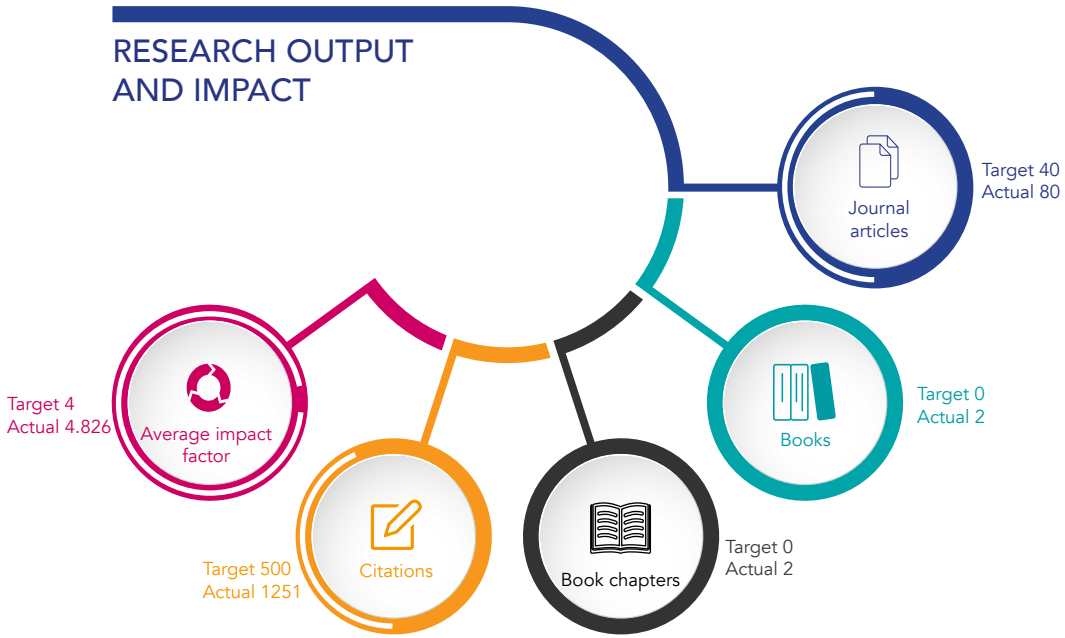
By focusing on the complex brain functions that underlie attention, prediction and decision-making, Centre researchers are undertaking fundamental investigations into the principles of brain structure and function. The Centre is studying the relationship between brain activity and behaviour at multiple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

Highlights

RESEARCH OUTPUT AND IMPACT



PERSONNEL

Postdoctoral researchers Target 25 Actual 26

PhD students

Target 25

Actual 32

Affiliate investigators

Target 70 | Actual 136

COMMUNITY

Primary & secondary education programs Target 3 Actual 5

Web hits

Target 20,000

Actual 39,732

Media articles

Target 15 | Actual 34

INTERNATIONAL PROFILE

74 International Collaborators

International presentations
Target 25 Actual 58

International visitors
Target 10 Actual 32

Director's message

A commitment to achieve impact is a fundamental tenet of the ARC Centre of Excellence Program. The ARC Centre of Excellence for Integrative Brain Function is continuing to have a major impact on the national and international reputation of the Australian neuroscience research community. During 2018 integration across the Centre's research programs continued to strengthen, with further substantial progress made towards achieving the scientific goals of the Centre.

The 2018 Science Meeting program was organised by Centre Early Career Researchers Roger Marek and Saba Gharaei, who were assisted by Chief Investigators Paul Martin and Jason Mattingley. The meeting was held in December 2018 in Brisbane with the theme of "Paint an Even Bigger Picture". The Science Meeting included presentations from a wide range of exciting new developments in brain research from both Centre members and researchers collaborating with Centre investigators. The program included sessions on cognition and addiction; sensory processing in the cortex; decision making; and memory, attention and executive control. We were delighted to host one of the Centre's international Partner Investigators, Dr Keiji Tanaka, from the RIKEN Centre for Brain Science in Tokyo, Japan, who presented one of two keynote lectures of the program.

The Centre's Early Career Researcher (ECR) activities in 2018 were planned and implemented by the elected Committee to address the interests of the ECR group. These activities included an ECR retreat with workshops on research funding, handling biases, entrepreneurship, science communication and work-life balance. There were also plenty of opportunities for our young researchers to share their current research projects, highlight their own technical and scientific expertise, and to forge new collaborations with their Centre peers around the country.

During the past year a new Strategic Research Initiatives program enabled the Centre's associate researchers to receive direct and indirect funding for their Centre related research projects. The expansion of the Strategic Initiatives Project program to Associate Investigators has been highly beneficial, with another three projects approved in 2018 which funded multidisciplinary research projects driven by Centre AIs, also involving ECRs and CIs, which advance the Centre's research agenda.

A new initiative of the ECR Executive Committee, the Future Leaders Accelerator (FLA) program, was introduced to advance early career researchers along a path to scientific independence by preparing them to secure funding from highly competitive sources. Along with workshops on grant-craft and career pathways and sustainability, the FLA featured a 'Three-Minute Fellowship' competition, where Centre ECR researchers pitched their ideas at the annual Centre dinner in Brisbane. Participants were scored against scientific quality, impact, innovation, feasibility, and the integration of multiple disciplines and levels of neuroscience, with prizes of funding to acquire pilot data or produce preliminary results towards the eventual submission of the grant to a major funding body. All in just 180 seconds! This made for a very entertaining and scientifically enlightening event.

The Centre's Neuroethics Program continued to grow under the leadership of Program Coordinator Adrian Carter with numerous workshops and public engagement activities held in 2018, including the fantastic 'Brave New Brains' event in Melbourne in August on the current and future challenges of brain-machine interfaces. Our neuroscience engagement program, the Brain Dialogue, published 27 'Discovery' pieces online highlighting Centre research outcomes in plain English. A total of 98 Discovery pieces have been published since the Centre's establishment, playing a crucial role in informing the broader community on cutting-edge Australian brain research.

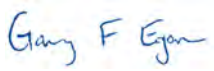
An international research highlight was a Centre symposium organised by CI Michael Ibbotson and Centre Advisory Board member Ulf Eysel in Berlin in July as part of the FENS Forum of Neuroscience conference program. Centre Associate Investigators and Postdoctoral Fellows also travelled to participate in the symposium, *Receptive fields: analysis, models and applications.*

I would like to thank the Centre's Executive team and Chief Investigators who continue to drive collaborative research into the integrative functions of Attention, Prediction and Decision, and who make significant contributions to the Centre's governance, education, outreach and other programs.

Sincere thanks to Chairperson Lyn Beazley and the Centre's Advisory Board for their oversight, expertise and guidance in the direction of the Centres research and other programs. Thank you to our expert and efficient Node Administrators at each of the Collaborating Organisations around the country, and to our Central Theme administrative team, for their efforts to keep the Centre running smoothly and our reporting and compliance on track. Minimising administrative burden on our researchers and allowing them to focus on their science is greatly appreciated.

In 2018 we initiated planning to develop alternate pathways to support the current research, educational and outreach, and community engagement by the Centre post-2020. Our goal is to capitalise on the Centre's established collaboration and administrative structures to coordinate and support the Centre's program beyond the current funding for the Centre. As we enter the final two years of the Centre for Integrative Brain Function I am proud of the efforts made over the past few years, and particularly in 2018, by all Centre members towards our goal of unlocking the mysteries of how the brain interacts with the world.

Consolidating the Centre's legacy of outstanding neuroscience research and the development of the next generation of neuroscience researchers, as well as the broader social impact of the Centre's activities is now a major focus during the last two years of the Centre.



Professor Gary Egan, 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. The Centre's researchers investigate brain activity at multiple scales of the brain in order to understand how neural processes associated with attention, prediction and decision-making are integrated and manifest in higher cognition, and ultimately behaviour.

Throughout the past year the Centre has continued to meet this significant challenge and has made a number of important discoveries that provide insights into the mechanisms of integrative brain function. It is pleasing to see the continued upward trend of scientific publications by the Centre's researchers, and the increasing citations reflecting the quality and impact of the science. An increasing number of Centre researchers were invited to present plenary and keynote addresses at international meetings, highlighting the unique strengths of the Centre's collaborative and multiscale research program into the principles of integrative brain function.

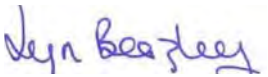
I was delighted to witness during 2018, as in previous years, the passion shown by the Centre's Early Career Researchers not just by their research efforts, but by contributing to the Centre's education and outreach programs. Many of the Centre's young neuroscientists volunteered to travel to primary schools around the country to present awards to those children who won the Centre's national annual brain art competition. I commend them for their work talking to and playing educational games with the primary school students and teaching them about the wonders and mysteries of the brain. This is truly a terrific example of the dedication and commitment by our Centre's Early Career Researchers to promote neuroscience and foster the next generation of brain researchers.

As a Centre we have a responsibility to ensure that we support and represent our Centre 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. In 2018 the Centre Gender, Equity and Diversity Coordinator Professor Melinda Fitzgerald, and her volunteer committee (comprising Centre Fellows and Associate and Chief Investigators), did a fantastic job in establishing a number of important initiatives to support equity and diversity. The initiatives were undertaken both within the Centre and in events organised by the Centre in the research and broader communities. The Committee's work is putting the Centre in the vanguard to promote equity and diversity within the Australian brain research community.

One specific initiative by the Gender, Equity and Diversity Committee was professional training in diversity and inclusion for Centre personnel, particularly those who have responsibilities within their organisations for recruitment. The training has a particular focus on unconscious bias and inclusive leadership. The Centre's leadership team recognises the personal challenges and pressures of being a researcher, and in particular the difficulties faced by those researchers for whom English is not their first language. I'm delighted that during 2018 the Early Career Researcher group, with the support of the Centre's Executive, promoted the development of workshops and shared resources to help address these challenges.

Thank you once again to my fellow Board members for their commitment to providing governance, support and advice for the Centre. Their combined expertise in scientific research nationally and brain science globally, as well as in broader cultural and financial issues, is an incredible resource for the Centre. In particular, the passion and experience brought to the Centre's education, outreach and non-research programs by the Board is energising and inspiring to all. I would like to thank all of the Centre's researchers, staff, PhD students, postdoctoral research fellows and supporters for their outstanding efforts and wonderful contributions during 2018. Thank you in particular to the Centre's Director, Professor Gary Egan, for his inspired leadership of the Centre, and to the Centre's Manager, Dr Glenn Papworth and his administrative team for their tireless work and dedication to achieving the Centre's goals.

I am greatly looking forward to learning about the Centre's achievements throughout 2019 which I am sure will result in further significant contributions to our understanding of how the brain interacts with the world.



Adjunct Professor Lyn Beazley AO

ORGANISATION & MANAGEMENT

Advisory board members at their annual face-to-face meeting in Brisbane. From L-R: Allan Jones, Jeanette Pritchard, Gary Egan, David van Essen, Lyn Beazley, Ulf Eysel, Jason Mattingley and Stella Clark.

Awarded in 2014 under the Australian Research Council Centres of Excellence Scheme, the Brain Function CoE is a seven-year research program funded by the ARC with contributions from six universities across Australia.

Led by Monash University (Administering Organisation), 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 (Collaborating Organisations), alongside QIMR Berghofer, and eleven international Partner Organisations across Europe, Asia and North America.

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, President and CEO, Allen Institute, Seattle, USA
- Dr Jeanette Pritchard, Executive Officer, The Garnett Passe and Rodney Williams Memorial Foundation
- Dr Stella Clark, Executive Director, Stella Connect Pty Ltd

SENIOR LEADERSHIP

Centre Director Prof Gary Egan oversees the Centre's research and operations while playing a key role in the development of industry engagement activities. Deputy Director Prof Marcello Rosa is instrumental in the development of international collaborations and partnerships and acts as an alternate for Prof Egan. Associate Director Prof 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 Prof 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 2018, the Executive Committee met monthly and comprised:

- Prof Gary Egan, Director, Brain Function CoE, Monash University
- Prof Marcello Rosa, Deputy Director, Brain Function CoE, Monash University
- Prof Jason Mattingley, Associate Director, Brain Function CoE, Brain Systems, University of Queensland
- Prof Pankaj Sah, Networks & Circuits, University of Queensland
- Prof Greg Stuart, Cells & Synapses, Australian National University
- Prof Peter Robinson, Models, Technologies & Techniques, 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 and public education and outreach. Administrative assistants are employed at each of the five nodes outside of the Central Theme, to assist with reporting and administrative functions of each node and ensure an integrated approach to reporting and administration.

PROGRAM COORDINATORS

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 to address societal, ethical, educational, computational and industry issues raised by brain research.

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

EARLY CAREER RESEARCHER COMMITTEE

The Centre continues to support Early Career Researchers (ECRs), including PhD students, by offering professional support, development and mentoring opportunities. The ECR cohort were brought together to elect an Executive committee to represent their interests at Centre meetings, and to coordinate events and activities to support their research interests and professional development requirements. The 2018 elected committee facilitated an inaugural ECR retreat, as well as continued to commit funding to an inter-lab exchange program, travel award funding and state-based events to foster networking and collaboration.

The ECR Committee meets monthly and reports to the Executive Committee twice per year. The 2018 representatives on the ECR committee were:

- QLD: Dr Roger Marek
- NSW: Dr Paula Sanz-Leon
- ACT: Dr Ehsan Kheradpezhouh
- VIC: Dr Phillip Ward

Personnel

Chief Investigators
Management & Administration
Program Coordinators
Partner Investigators
Associate Investigators
Centre Fellows
Centre Scholars
Honours Students
Affiliate Academics
Affiliate Professional Staff
Affiliate Fellows
Affiliate Scholars
Collaborators

Multi-institutional collaborative research being undertaken by Centre ECRs. From L-R: Centre Scholar Cong Wang, University of Queensland; Centre Fellow Dr Teri Furlong, University of New South Wales; Centre Fellow Dr Roger Marek, University of Queensland; Centre Fellow Dr Tim Karle, University of Melbourne; Centre Affiliate Fellow Dr Sam Merlin, Western Sydney University

CHIEF INVESTIGATORS

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

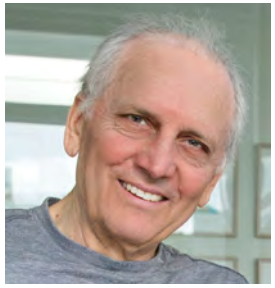
Marta Garrido
Chief Investigator
University of Queensland

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

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

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
- Maria del Mar Quiroga, Outreach and Education Officer (to April 2018), 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 Ursino, Node Administrator (Mat leave), Australian National University
- Eliorah Malifa, Node Administrator (Mat leave replacement), Australian National University

PROGRAM COORDINATORS

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

PARTNER INVESTIGATORS AND ORGANISATIONS

- Michael Breakspear, QIMR Berghofer Medical Research Institute
- Matthew Diamond, International School for Advanced Studies, Italy
- 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
- Human Brain Project, Switzerland
- Partha Mitra, Cold Spring Harbor Laboratory, USA
- Tony Movshon, New York University, USA
- Keiji Tanaka, RIKEN Center for Brain Science
- Jonathan Victor, Weill Cornell Medicine, USA

ASSOCIATE INVESTIGATORS

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

CENTRE MEMBER PROFILE

Prof Trichur Vidyasagar (Sagar)

Associate Investigator, University of Melbourne

After his medical studies at the University of Madras and a PhD at the University of Manchester, Sagar worked at the Department of Neurobiology at the Max-Planck Institute for Biophysical Chemistry, Germany, before moving to Australia for a position at the Australian National University, and subsequently, the University of Melbourne.

Sagar's research has included the first demonstrations of the neural mechanisms of top-down attention in the visual system, insights into the development of basic response properties and functional architecture of the primary visual cortex, and a new model of the neural basis of reading that has challenged classical ideas of the cause of dyslexia.

He is currently working on collaborative projects with other Centre researchers, alongside CI Jason Mattingley, CI Steve Petrou and Centre Fellow Matthew Tang on cortical mechanisms of predictive coding and top-down attention in macaques. In 2018, in recognition of his lifetime achievements, he was awarded the Gauss Professorship of the University of Goettingen to work at the German Primate Centre in 2018-19.

CENTRE MEMBER PROFILE

Dr Sharna Jamadar

Senior Research Fellow, Monash University

Sharna completed her PhD in Psychology at the University of Newcastle in 2010. Following her PhD, she completed a postdoctoral fellowship at the Institute of Living- Olin Neuropsychiatry Research Center, Connecticut, USA, and returned to Australia to take up a research position at Monash University, where in 2014 she was awarded an ARC DECRA Fellowship. Sharna is an expert in multimodal neuroimaging, and is contributing to the development of novel MRI-PET measures that provide high resolution mapping of the function, structure, and metabolic efficiency of the brain.

Sharna is committed to service and advocacy in the scientific and general communities, co-founding the Australasian Women in Neuroscience Network and serving on the Centre's Gender Equity and Diversity Committee. In 2018 she was recognised by Science & Technology, Australia as a Superstar of STEM, which will see her undertake a series of professional development opportunities designed to support women in scientific roles and increase the public visibility of women in STEM.

CENTRE FELLOWS

- Massoud Aghili Yajadda, University of Sydney
- Tahereh Babaie, University of Sydney
- Ilvana Dzafic, University of Queensland
- Calvin Eiber, University of Sydney
- Timothy Feleppa, Monash University
- Teri Furlong, University of New South Wales
- Demi Gao, University of Sydney
- Kelly Garner, University of Queensland
- Saba Gharaei, Australian National University
- Sharna Jamadar, Monash University
- Tim Karle, University of Melbourne
- Ehsan Kheradpezhouh, Australian National University
- Stuart Knock, University of Sydney
- Sammy Lee, University of Sydney
- Roger Marek, University of Queensland
- Hamish Meffin, University of Melbourne
- Anand Mohan, Monash University
- Babak Nasr, University of Melbourne
- David Painter, University of Queensland
- Alexander Pietersen, University of Sydney
- Guilherme Silva, Australian National University
- Matthew Tang, University of Queensland
- Phillip Ward, Monash University
- Dongping Yang, University of Sydney
- Elizabeth Zavitz, Monash University
- Natalie Zeater, University of Sydney

CENTRE SCHOLARS

- Sahand Assadzadeh, University of Sydney
- Ashleigh Chandra, University of Sydney
- Guozhang Chen, University of Sydney
- Farah Deeba, University of Sydney
- Guthrie Dyce, Australian National University
- Daniel Fehring, Monash University
- Mariya Ferdousi, University of Sydney
- Natasha Gabay, University of Sydney
- Yifan Gu, University of Sydney
- Suraj Honnuraiah, Australian National University
- Thomas Lacy, University of Sydney
- Xiaochen Liu, University of Sydney
- Yuxi Liu, University of Sydney
- Xian Long, University of Sydney
- Dan Ma, University of Sydney
- Rania Masri, University of Sydney
- Jessica McFadyen, University of Queensland
- Kamrun Mukta, University of Sydney
- Eli Muller, University of Sydney
- Brandon Munn, University of Sydney
- Daniel Naomenko, University of Sydney
- Suba Nasir-Ahmad, University of Sydney
- Shencong Ni, University of Sydney
- Edwina Orchard, Monash University
- James Pang, University of Sydney
- Yang Qi, University of Sydney
- Kevin Qu, University of Sydney
- Angela Renton, University of Queensland
- Nipa Roy, University of Sydney
- Taylor Singh, Australian National University
- Christodoulos Skilros, University of New South Wales
- Cong Wang, University of Queensland
- Asem Wardak, University of Sydney
- Iris Zhu, Monash University

CENTRE MEMBER PROFILE

James Pang

PhD Scholar, University of Sydney

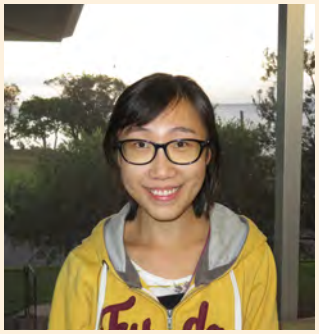
James is a PhD candidate, who under the supervision of Peter Robinson at the University of Sydney, submitted his final thesis for examination in late 2018 (awarded in Feb 2019). His thesis focussed on the fundamentals and applications of hemodynamics to fMRI modelling and analysis, which led to several high-profile publications, including an article published in *NeuroImage* (a top ranked Journal in the field of Neuroscience with a 5yr Impact factor of 7.079).

James' work has also led to the development and release of a publicly available code package for fMRI analysis, which saw him awarded the David van Essen Award for Outstanding Early Career Researcher at the Centre's annual AGM and Science meeting.

CENTRE MEMBER PROFILE

Cong Wang

PhD Scholar, University of Queensland



Cong is a second-year PhD candidate under the supervision of Pankaj Sah at the Queensland Brain Institute (QBI). With a background in biomedical science, Cong's research focuses on the role of the medial prefrontal cortex and the hippocampus in memory and learning. She uses in vivo electrophysiological techniques alongside animal behavioural tasks, in order to understand the neural activity and connectivity pattern in both the single neuron and local field potential scales, with the ultimate aim of deciphering mechanisms of memory formation and retrieval.

In 2018 she was one of 11 (and the only Australian student), to have been awarded the Edmond and Lily Safra Center for Brain Sciences (ELSC) PhD Travel Grant, providing an opportunity to attend the 2018 Ein Gedi retreat of the ELSC at Hebrew University, Israel. This multidisciplinary neuroscience retreat offers an unprecedented opportunity for advanced PhD students to present their work and receive expert feedback. The retreat also included the chance to visit ELSC labs, exploring opportunities for potential postdoctoral placements and collaborations.

HONOURS STUDENTS

- Elissa Belluccini, University of Sydney
- Alex Chin, Monash University
- India Cowie-Kent, Monash University
- Tayla Donegan, Monash University
- Yotam Eren, Monash University
- Erin-Louise Gibbs, Monash University
- Lachlan Gorey, University of Sydney
- Jess Hamley, University of Sydney
- Alan Ly, Monash University
- Perri Newman, University of Queensland
- Edwina Shi, University of Queensland
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- Arzu Demir, University of Sydney
- Ilvana Dzafic, University of Queensland
- Daria Malmanova, Monash University
- Afsah Zaheer, University of Sydney

From L-R: Centre Scholars Brian Oakley, Daniel Fehring and Jamie McFadyen at the 2018 ECR workshop in Brisbane.

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- David Garret, University of Melbourne
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- Leo Lui, Monash University
- Bernard Pailthorpe, University of Sydney
- Svetlana Postnova, University of Sydney
- Steven Prawer, University of Melbourne
- David Reser, Monash University
- Margreet Ridder, University of Queensland
- Mark Schira, University of Wollongong
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- Francois Windels, University of Queensland
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- Jonathan Chan, Monash University
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- Ianina Hutler-Wolkowicz, Monash University
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- Perri Newman, University of Queensland
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- Kirsty Watkins, Monash University
- Katrina Worthy, Monash University
- Li Xu, University of Queensland

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- Lei Qian, University of Queensland
- Dragan Rangelov, University of Queensland
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- Yajie Sun, University of Queensland
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- Hsin-Hao Yu, Monash University
- Molis Yunzab, University of Melbourne

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- Declan Rowley, Monash University
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- Artemio Soto-Breceda, University of Melbourne
- Shi (Scott) Sun , University of Melbourne
- Susan Travis, University of Queensland
- Chalini Wijetunge, University of Melbourne
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- Teresa Wulandari, Monash University
- M S Zobaer, University of Sydney

COLLABORATION NETWORK

74 International collaborators from 21 countries

34 National collaborators

23 Visits to international laboratories

Hover over location markers for full lists

Research report

Centre ECRs in the Ibbotson Laboratory, University of Melbourne. From L-R: Centre Fellow Dr Molis Yunzab, Centre Affiliate Scholar Young Jun (Jason) Jung, Centre Affiliate Fellow Dr Ali Almasi; Centre Affiliate Scholar Shi (Scott) Sun

VISION

To understand how the brain interacts with the world.

MISSION

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

KEY INTEGRATIVE BRAIN FUNCTIONS

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

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

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

RESEARCH THEMES

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

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

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

Models, Technologies & Techniques
The development and use of novel neurotechnologies, experimental instruments and computational tools.

RESEARCH PROGRAM

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

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

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

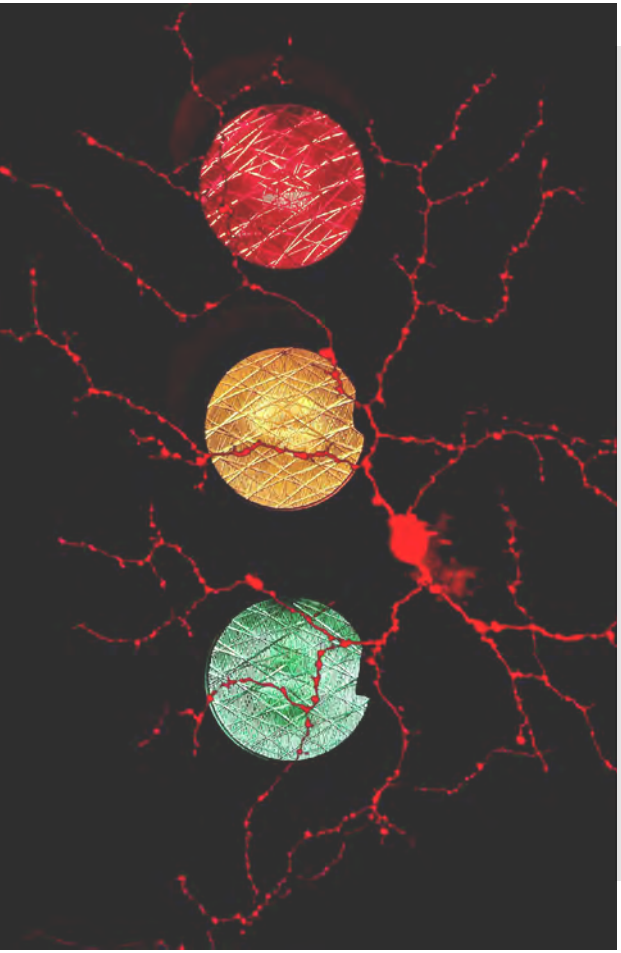
Attention - What are the neural mechanisms of selective attention?
Prediction - How do "error messages" influence the brain's capacity for prediction?
Decision - How is information from the sensory environment used to make decisions?

In 2018 this approach has developed further 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 2018.

CELLS & SYNAPSES

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



CELLS & SYNAPSES

Organisation of cortical interneurons in marmoset

Investigators: Marcello Rosa, George Paxinos, Teri Furlong, Nafiseh Atapour, Sam Merlin.

Knowing how different cell types within the cortex are organised will aid in our understanding of how the brain functions.

The cortex is divided into separate regions that have specialised functions, like memory versus vision, and we suspect that the arrangement of neurons across the different layers of these regions differ.

The cells that we are interested in are known as interneurons, and they have a modulatory role on brain activity. We are identifying the different types of interneurons by immunostaining their unique proteins (parvalbumin, somatostatin and calbindin), and then mapping their specific location across the layers of the cortex in the marmoset.

We are also determining whether the arrangement of interneurons changes with age, by comparing the distribution of cells between young and old monkeys. This level of brain mapping, that identifies the exact location of each cell type, is required to fully understand the organisation of cortex.

NEXT STEPS

We are optimising protocols, primarily staining of parvalbumin and somatostatin staining on cortical tissue in mice and marmoset tissue, and then trouble shooting the best methods for obtaining images of the brain that reveal both the necessary detail of the cells, but do not create tiling artefacts or unmanageable file sizes.

RELATED PUBLICATION

Expanding your mind: Areas of the brain that have evolved to be much bigger in humans than in other primates act as communication hubs.

PUBLICATION IN A NUTSHELL

Expanding your mind

Areas of the brain that have evolved to be much bigger in humans than in other primates act as communication hubs.

One of the biggest differences between humans and other primates is the size of our cerebral cortex. This thick folded layer of cells, which covers much of the surface of the brain, has evolved to contain more cells and span a much bigger area in humans. Not all parts of this brain region have increased at the same rate over time, however; some areas have expanded more quickly than others during evolution.

Maintaining a greater number of brain cells takes more energy away from other important processes in the body, so these high-expanding brain regions must have a useful function – an evolutionary advantage – in humans.

Using a mix of scientific approaches, Brain Function CoE investigator Marcello Rosa and colleagues from Monash University, along with researchers in Norway, sought to discover what that function might be.

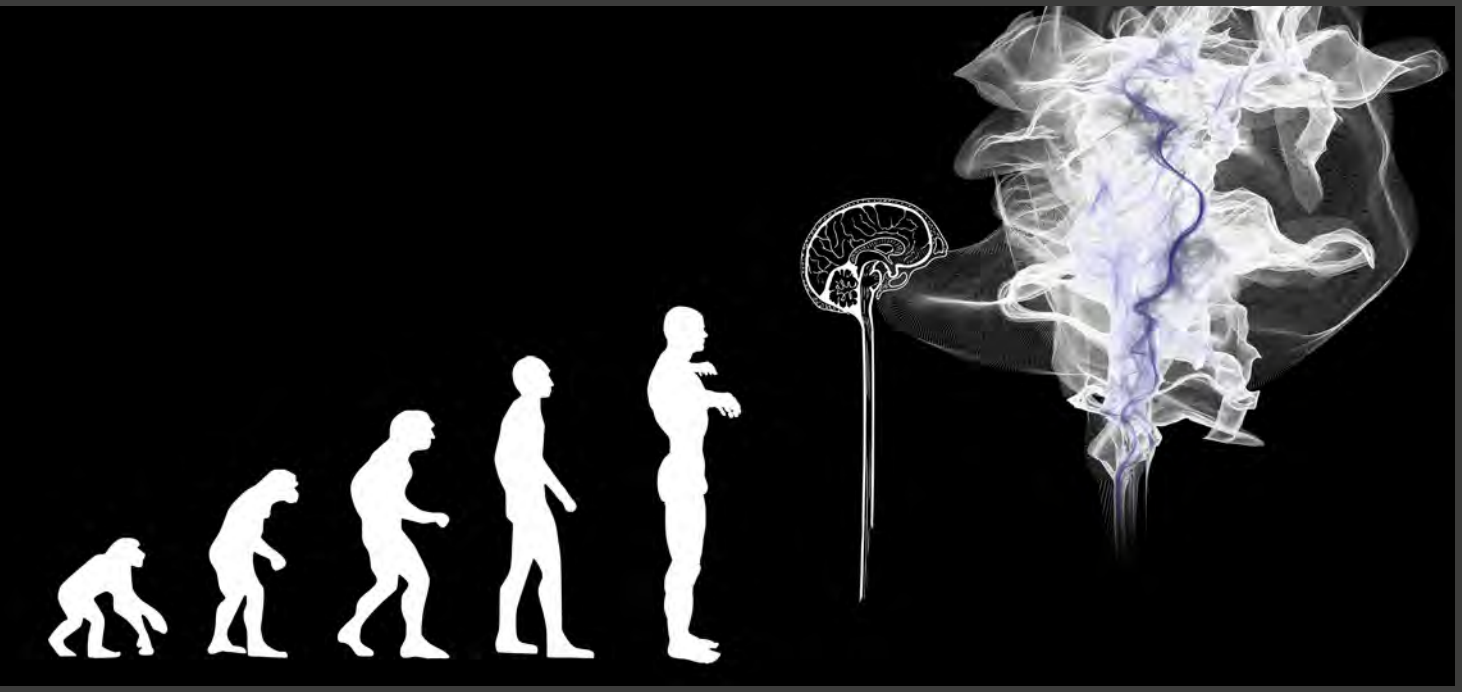
The researchers began by comparing the size of the cerebral cortex in four primate species – marmoset, capuchin and macaque monkeys and humans. This analysis identified the 'high-expanding' regions of the cerebral cortex – the areas that have expanded more quickly than others during evolution. It also showed more of these regions in humans than in non-human primates.

The researchers then used functional magnetic resonance imaging (fMRI) to measure the brain activity of more than 200 children and adults while they rested with their eyes closed or performed cognitive tasks. From this data, the researchers could tell which regions of the cerebral cortex were more active during the different tasks, and how those regions were connected to other areas of the brain.

To see how brain evolution is linked to brain behaviour, the researchers compared the fMRI data to the maps of the cerebral cortex. They found that the high-expanding regions connected more flexibly to other parts of the brain, with the precise connections depending on the brain activity that a specific cognitive task required. These regions were particularly active during tasks that required different types of information to be integrated.

By looking at the brain activity in people of different ages, the researchers also found that the high-expanding regions are among the last in the brain to mature – they don't become fully functional until early adulthood. In addition to being late to appear in evolution, it seems they are late to develop in the human brain.

This research offers one explanation for why humans have evolved to devote valuable energy to the maintenance of more brain cells: to create communication hubs that can transmit information flexibly, enabling us to carry out more complicated cognitive tasks.



VIEW PAPER ABSTRACT

NEXT STEPS

The researchers are now using higher-resolution techniques, capable of identifying the connections of single cells, to explore the connectivity of the areas of the cortex that have expanded the most. This will allow them to obtain more insight into what functions have driven the evolution of the human brain.

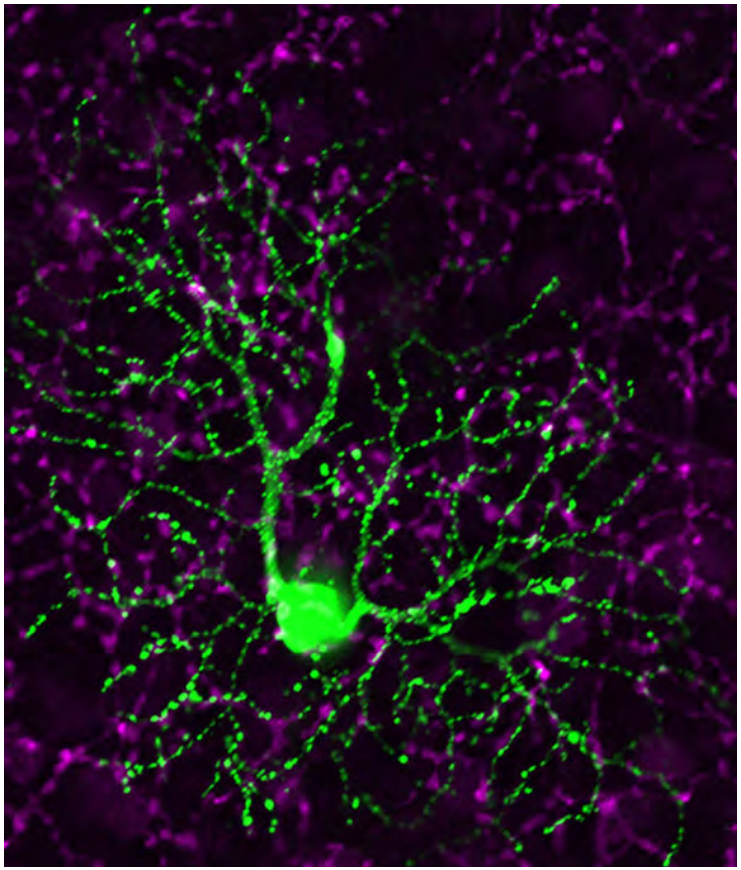
Reference:
Sneve, M. H., Grydeland, H., Rosa, M. G. P., Paus, T., Chaplin, T., Walhovd, K., & Fjell, A. M. (2018). High-expanding regions in primate cortical brain evolution support supramodal cognitive flexibility. Cerebral Cortex. doi: 10.1093/cercor/bhy268

CELLS & SYNAPSES

Mapping retinal cell types and their role in attention

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

About 20 morphological types of retinal ganglion cells which are involved with distinct visual pathways have been discovered in primates, yet only six are well understood.



This project links the Cells and Synapses and Neural Circuits themes by using a molecular-based strategy for identifying parallel inputs to brain circuits for attention in the primate visual system.

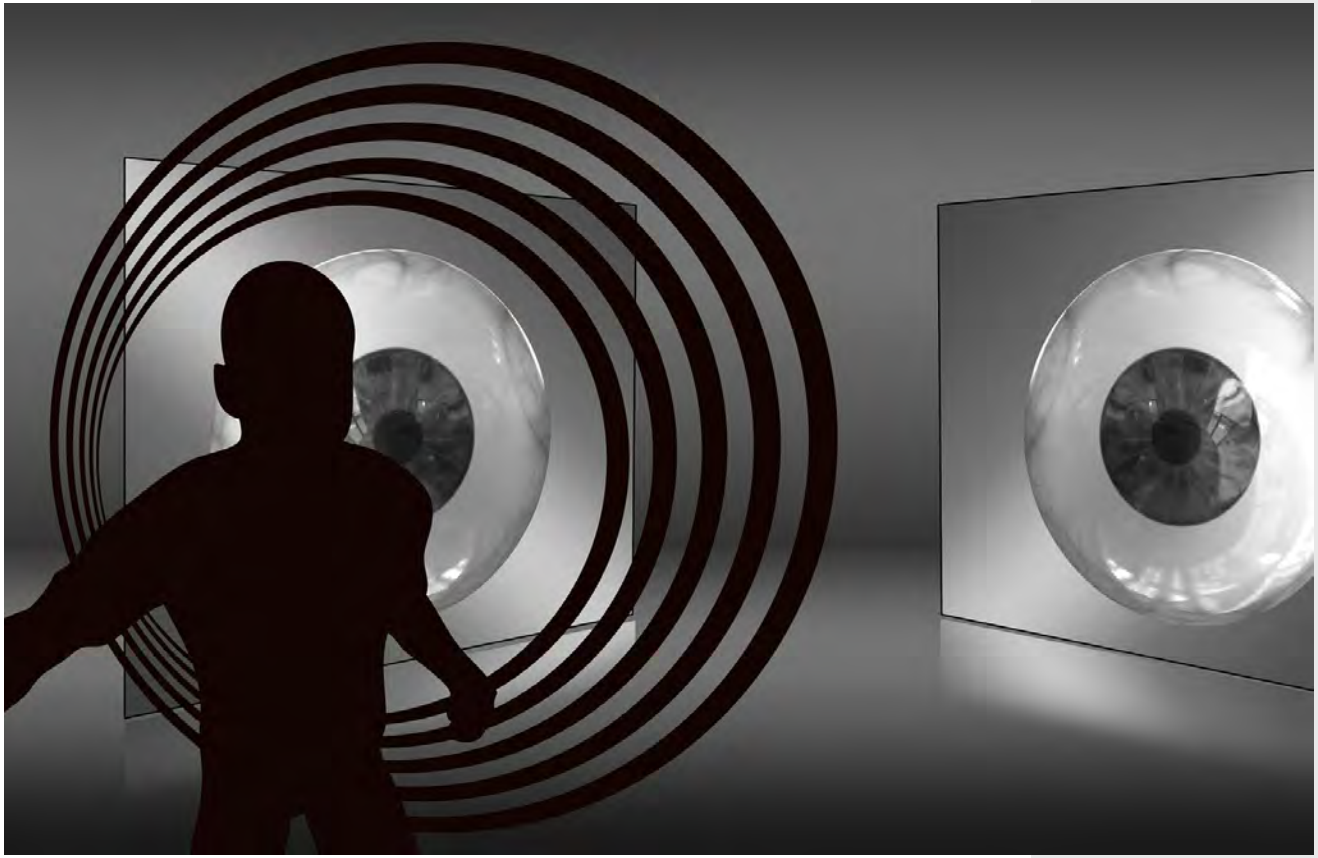
About 20 morphological types of retinal ganglion cells which are involved with distinct visual pathways have been discovered in primates. Yet only six of these ganglion cell types are well understood and it is expected that at least 10 more types are yet to be discovered. Some of these ganglion cell types project to subcortical brain centres involved in rapid detection of environmental threats and opportunities, and are specifically processing information from the peripheral visual field (“corner of the eye”). Very little is known about these cell types, their specific connections within the retina, and their patterns of projection to the brain.

Recently, molecular markers for retinal ganglion cell types have been developed in mouse retina. We are applying antibodies with molecular markers to marmoset and macaque retinas and use intracellular injection to reveal the morphology of the cells. This method allows us to find out how many retinal cell types there are and how they connect to brain circuits for attention.

NEXT STEPS

To continue identifying the different morphological types of retinal ganglion cells, with the aim to identify functional variability.

One key question in neuroscience is how the external world is represented in the brain and how this representation is used to generate appropriate behavioural responses.



CELLS & SYNAPSES

Cellular and circuit mechanisms underlying sensory processing in cortex

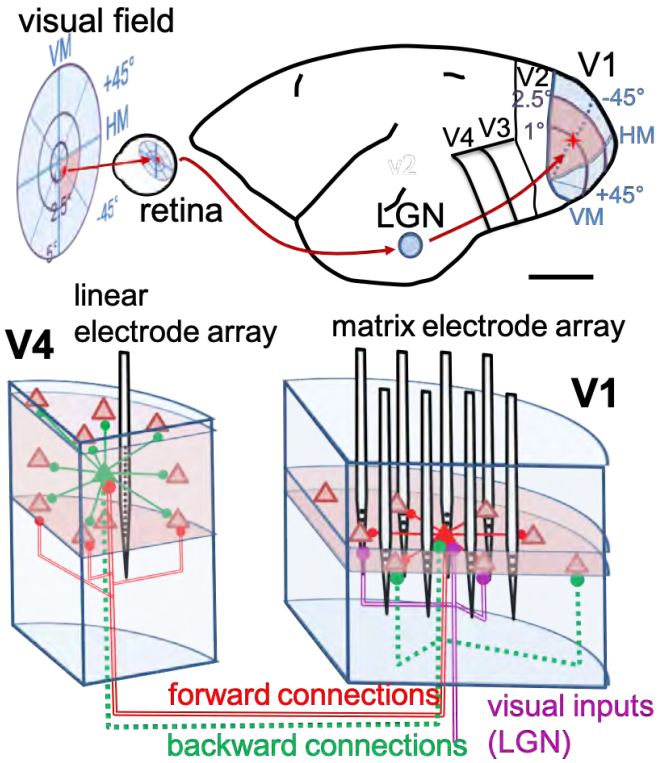
Investigators: Greg Stuart, Ehsan Arabzadeh.

This project investigates how the activity of single cells and neuronal populations is involved in information processing in two sensory modalities – rodent whisker touch and vision. Both sensory systems comprise well-studied pathways and have elegant structural organisations containing orderly representations of the environment. This means that sensory signals are channelled through restricted populations of neurons that can be efficiently sampled via recording electrodes or imaging. In addition, this allows targeted and precise modulation of the neuronal circuits involved.

In this project we investigate sensory processing in the cortex at multiple levels. At the cellular level we study the synaptic and single cell properties involved in the integration of sensory information (e.g. inputs arriving from the two eyes). At the circuit and population level we investigate how sensory processing is influenced during decision making, prediction and attention. In particular, we characterise how the superior colliculus, a midbrain structure involved in orienting behaviour and attention, affects the processing of information in the sensory cortex. Finally, we use modelling and computational analysis to provide a framework for interpretation of data obtained at cellular and network levels.

NETWORKS & CIRCUITS

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



NETWORKS & CIRCUITS

Diversity of feature selectivity and invariance in primary visual cortex

Investigators: Michael Ibbotson, Ali Almasi, Yan Wong, Shaun Clohery, Hamish Meffin, Shi Sun

Object recognition in scenes develops across a hierarchy of visual areas. Robust recognition requires fine selectivity for particular features of relevance and invariance to irrelevant features. Deep convolutional neural networks have achieved near-human levels of performance in object recognition by iteratively applying filters that select features, followed by pooling their outputs to generate invariance.

We are developing nonlinear mathematical models to recordings from primary visual cortex (V1) that “filter-then-pool”, to investigate feature selectivity and invariance in the brain.

We have found a diversity of cells that combine selectivity for some feature characteristics with invariance to perturbations in others. Peak orientation had the greatest portion of selective cells (87%), followed by peak spatial frequency (71%), orientation bandwidth (66%), spatial frequency bandwidth (54%) and spatial phase (0%), the latter showing the greatest portion of invariance.

NEXT STEPS We will apply the same methodology to higher cortical areas such as V2 and V4 to understand how visual feature selectivity and invariance arises through the cortical hierarchy.

NETWORKS & CIRCUITS

A comparative study of the roles of the cortical and sub-cortical routes for processing fear in humans and rodents

Investigators: Pankaj Sah, Marta Garrido, Roger Marek, Cong Wang, Jessica McFadyen.

Responding to fear is an essential behavioural response. However, following exposure to a severely traumatising event, such normal physiological responses can disappear, culminating in many cases in the development of anxiety disorders.

Even though behavioural aspects of the fear response are well understood, the underlying neuronal mechanism still remains unclear.

Two main pathways for sensory inputs to the amygdala have been identified, which are called the cortical and the subcortical route. The subcortical route, currently thought to process fear-related processes that are rapid and non-conscious, enters the amygdala directly via the sensory thalamus.

In the cortical route, information is routed from the thalamus to the cortex and then processed information enters the amygdala. Thus this is thought to regulate conscious processing during fear learning.

These two pathways have been proposed based on behavioural experiments, however the nature of these pathways and their exact roles are not understood.

In the current project, we are using a rodent model that allows us to silence either the cortical or subcortical route using virally expressed receptors that respond to designer drugs (DREADDs), while recording neuronal activity during auditory fear-conditioning.

Complementing the animal experiments, human participants are undergoing similar auditory fear-conditioning, while recording brain activity using magnetoencephalography (MEG).

We are also using computational modelling to simulate the effects of same silencing of either the cortical or the subcortical routes in humans.

This approach will improve the knowledge about the neuronal circuitry that is recruited during fear and clarifies the understanding about inter-species difference that is critical to be able to translate animal models to human.

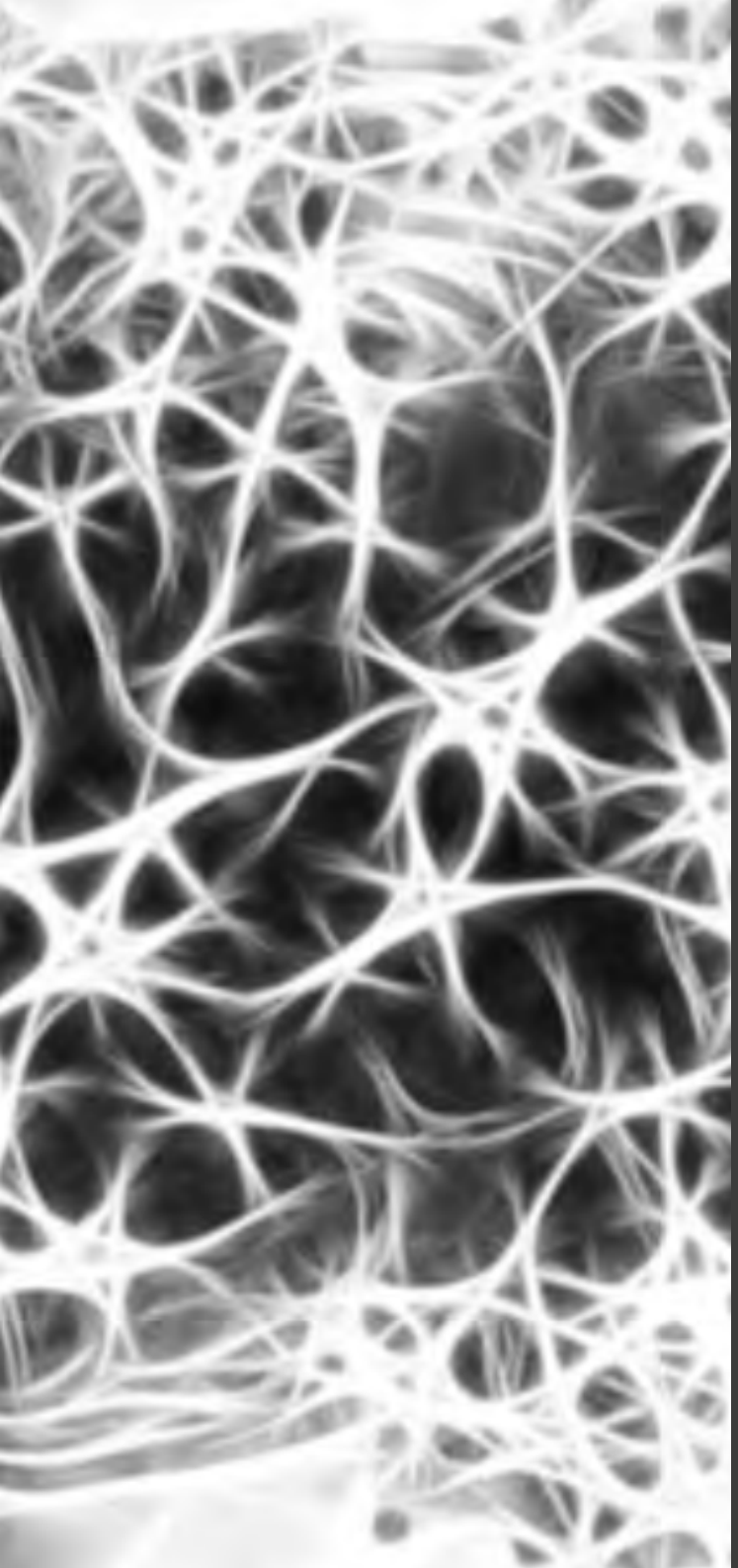
NEXT STEPS

We aim to update our system which will allow us to record more units from multiple sites (including the mPFC and hippocampus).

RELATED PUBLICATION

Redrawing the map of brain connections involved in extinguishing learned fear

Even though behavioural aspects of the fear response are well understood, the underlying neuronal mechanism still remain unclear.



PUBLICATION IN A NUTSHELL

Redrawing the map of brain connections involved in extinguishing learned fear

The identification of a new connection in the brain involved in reducing the fear response upends the current model of fear extinction.

When we feel fear in response to a threat, networks of brain cells work together to evaluate the threat, helping us to learn from experience and to react appropriately to dangerous situations. Dysfunction of these circuits – which involve several different parts of the brain – can lead to anxiety-related disorders such as post-traumatic stress disorder.

In certain circumstances, the brain can be trained to reduce the fear response – a process known as fear extinction. Behavioural studies suggested that fear learning and extinction both begin in the amygdala but are then regulated by distinct parts of the medial prefrontal cortex: the prelimbic (PL) for learning and the infralimbic (IL) for extinction. However, anatomical and electrophysiological studies have shown that the PL and IL are significantly connected.

To see if the PL is involved in fear extinction as well as fear learning, Brain Function CoE postdoctoral research fellow Roger Marek, chief investigator Pankaj Sah and colleagues from the Queensland Brain Institute mapped these connections in rats. They found not only that brain cells in the PL can send signals to cells in the IL, but also that activating this connection enhances fear extinction.

This discovery redefines the role of the PL and means that the current brain circuitry model of fear learning and extinction needs to be revised. The finding will also help us to better understand the brain circuits involved in anxiety disorders.

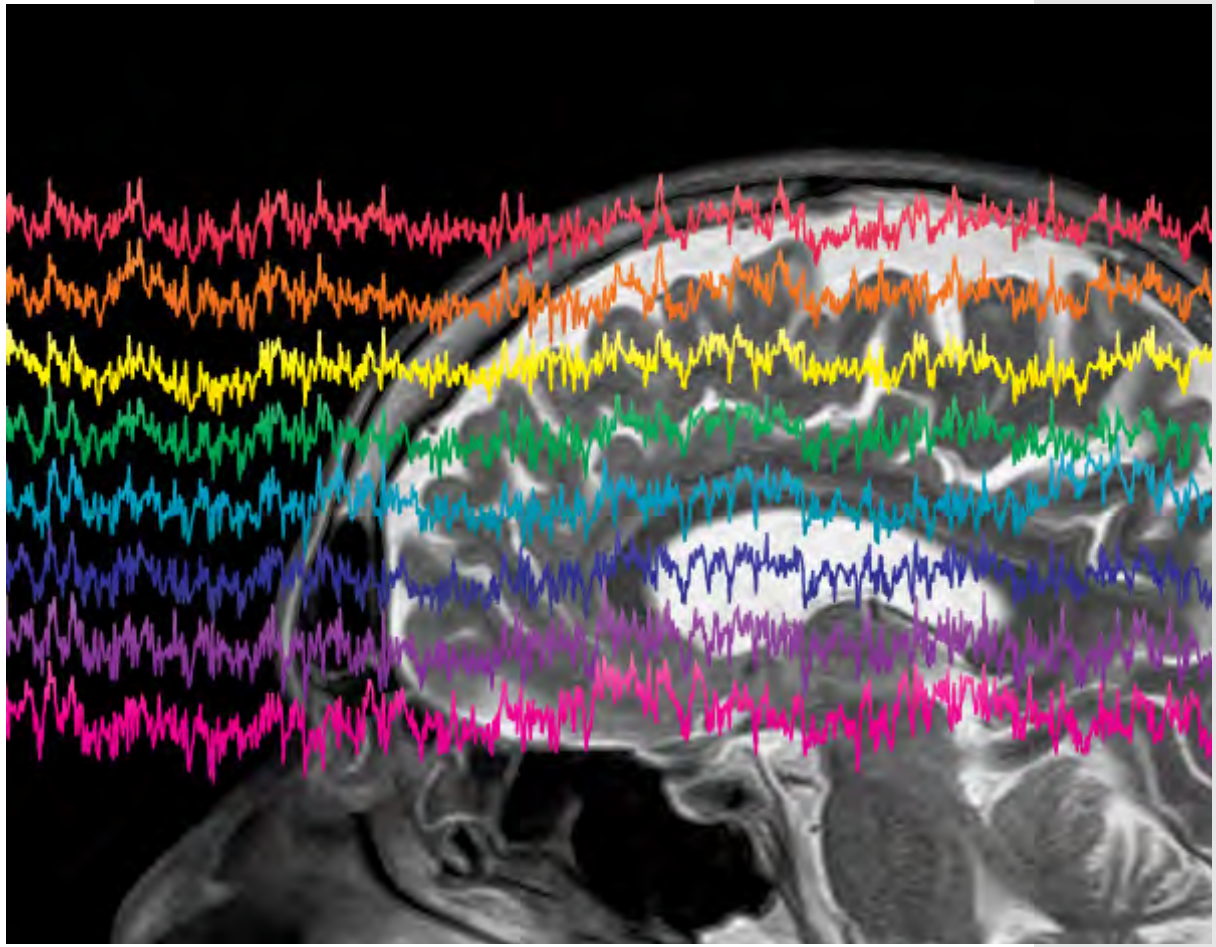
VIEW PAPER ABSTRACT

NEXT STEPS

The researchers are trying to identify the precise patterns of activity between brain cells that are involved in the opposing but related behaviours of fear learning and fear extinction.

Reference:
Marek, R., Xu, L., Sullivan, R. K. P., & Sah, P. (2018). Excitatory connections between the prelimbic and infralimbic medial prefrontal cortex show a role for the prelimbic cortex in fear extinction. Nature Neuroscience, 21(5), 654-658. doi:10.1038/s41593-018-0137-x

Through this collaboration we have discovered new self-similar (fractal) properties of nerve activity in the subcortical visual 'gateway' LGN



NETWORKS & CIRCUITS

Visual signal processing in thalamocortical loops; predictive coding in attentional circuits

Investigators: Paul Martin, Ulrike Grunert, Pulin Gong, Partha Mitra, Calvin Eiber, Alexander Pietersen, Sammy Lee, Natalie Zeater, Elissa Bellucini, Brandon Munn

The project looks at long timescale (slow) changes in brain activity that underlie modulated control of attention. We apply turbulence physics methods to lateral geniculate nucleus (LGN) and cross correlate with cortex (V1 and MT). We analyse differential connections of LGN to V1 and MT.

AI Pulin Gong has analysed cross-frequency coupling across electroencephalogram (EEG) frequency bands, and through this collaboration we have discovered new self-similar (fractal) properties of nerve activity in the subcortical visual 'gateway' LGN. Analysis of local field potentials in the geniculate, thalamic reticular nucleus, and cerebral cortex areas MT and V1 has also commenced.

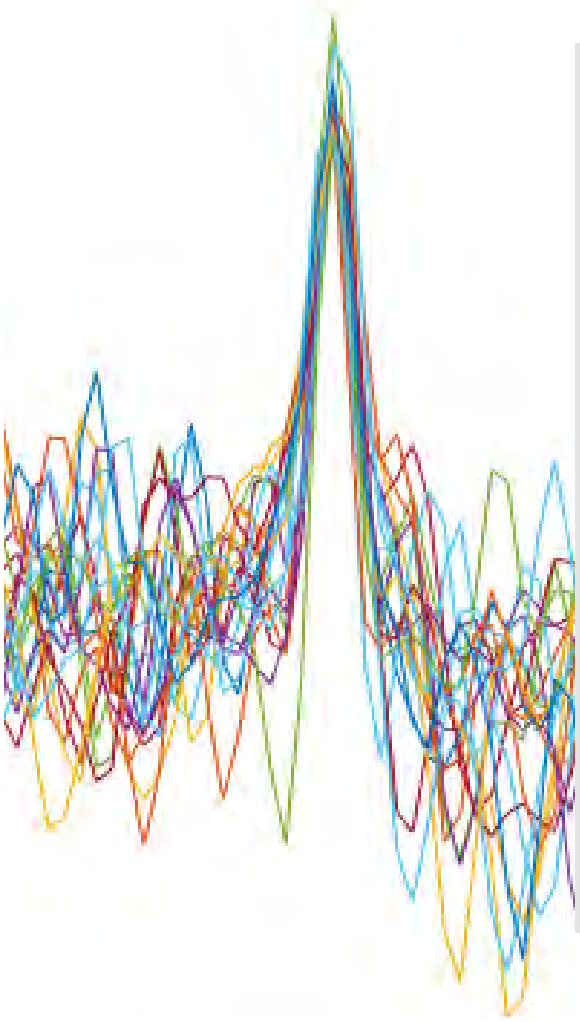
We have made preliminary array recordings in the visual pulvinar nucleus. This poorly-understood region of the thalamus is considered important for attentional modulation and rapid responses to environmental threats and opportunities. Initial results indicate complex motion-processing properties consistent with rapid detection of approaching visual threats. PI Partha Mitra is assisting with automatic analysis of brain pathways connecting cortex, thalamus, and tectum.

NEXT STEPS

We will combine the anatomical knowledge with our functional knowledge and modelling based on physiological data.

BRAIN SYSTEMS

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



BRAIN SYSTEMS

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

Investigators: Peter Robinson, Pulin Gong, Tahereh Babaie, Dongping Yang, Demi Gao, Sahand Assadzadeh, Eli Muller

The main strand of this project seeks to show how alertness, prediction, and decision emerge from the dynamics of the physical brain.

The brain is known to display particular dominant frequencies, or 'resonances', such as the 10 Hz alpha rhythm. By modelling brain dynamics using neural field theory (NFT) we have shown that each resonance acts like a device, called a PID controller, used in engineering to predict and control dynamics of systems as diverse as manufacturing processes and aircraft.

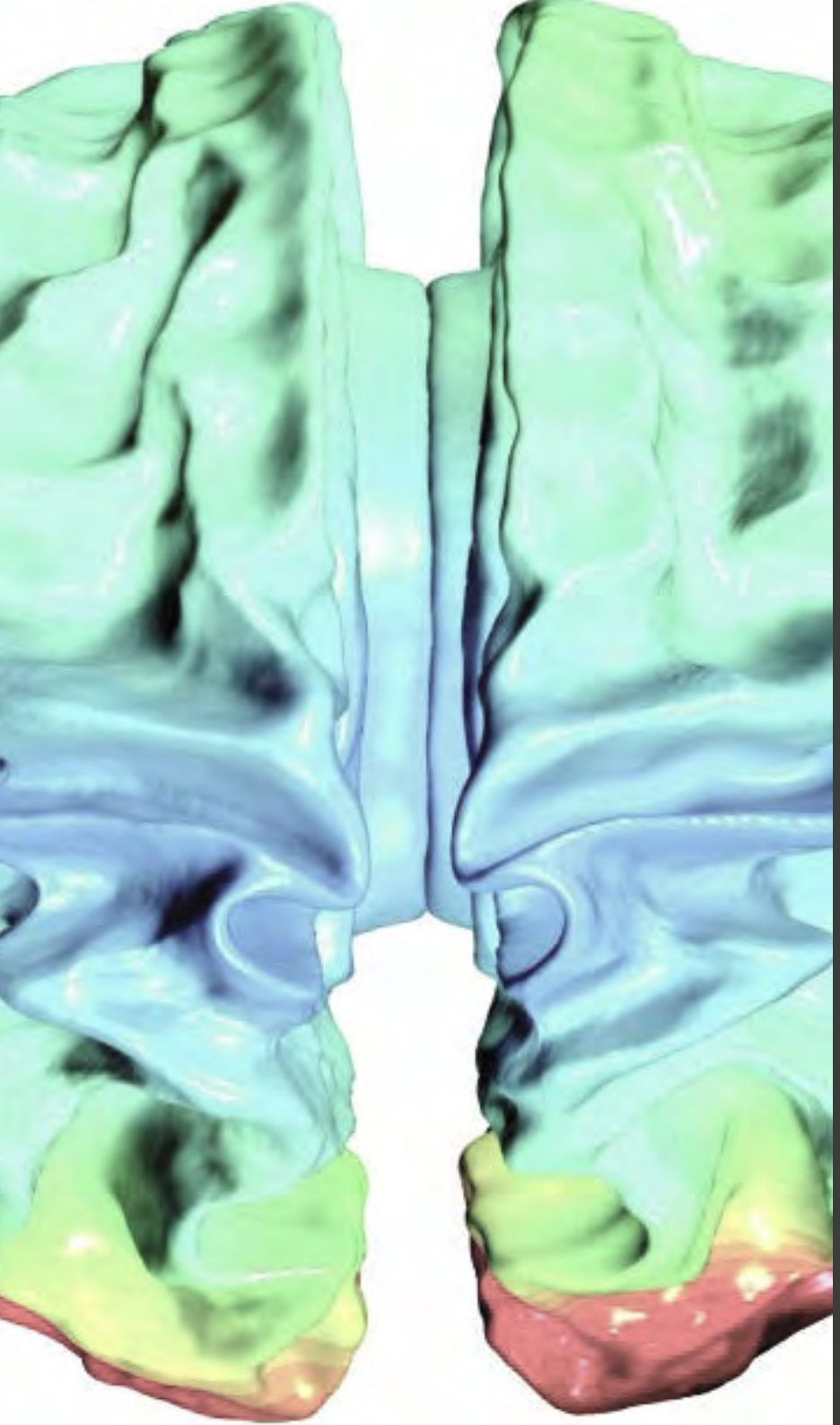
This has demonstrated that brain resonances predict the course of incoming signals and provide the means to adjust attention to focus on those that are most significant.

In other strands of the project, we are applying NFT to understand the links between the brain's structure and its dynamics by recognising that it is a physical system. This has uncovered and resolved serious problems with the most commonly used methods for studying these links.

NFT has also been successfully applied to understand and optimise brain stimulation methods and to track brain states.

NEXT STEPS We will persue applications of these results to controlling abnormal brain rhythms.

RELATED PUBLICATION Using physics to understand the 'music' of the brain.



PUBLICATION IN A NUTSHELL

Using physics to understand the 'music' of the brain

A physics-based approach successfully explains mysterious oscillations in brain activity that are like the notes produced by a musical instrument.

Our understanding of how the brain works has been based mostly on observation, with little ability to predict behaviour or analyse its underlying mechanisms. Techniques such as electroencephalography (EEG) are used to measure electrical activity in the brain and link it to brain function – or dysfunction.

When the cerebral cortex is stimulated in one location by randomly flickering light, EEG recordings show that the resulting brain activity oscillates in other locations in a way that is closely related to changes in the light. These oscillations, known as perceptual echo, were first discovered in 2012 but have remained a mystery ever since.

Perceptual echo might have implications for the processes involved in visual perception, so learning more about it could increase our understanding of human vision. However, there have been no studies to predict perceptual echo or analyse its underlying mechanisms.

Brain Function CoE Chief Investigator Peter Robinson and his colleagues from the University of Sydney aimed to fill this gap using neural field theory – a comprehensive model of the connections between brain stimuli, activity and measurements that is based on physics rather than statistics.

The researchers used neural field theory to predict the frequency and spatial patterns of perceptual echo by splitting the brain's oscillations into 'natural modes' (like the notes produced by a musical instrument) and their patterns on the cortex – as shown in the illustration, where strong oscillations in the visual cortex are shown in red. They found that two modes dominated, which closely matched experimental observations. This finding is comparable to striking a musical instrument, such as a drum: even if you hit it randomly, the resulting sound will be dominated by its favoured notes.

The team's work – which combined theory, experiment, and physical and biological sciences – demonstrates the power of interdisciplinary methods to explain brain activity.

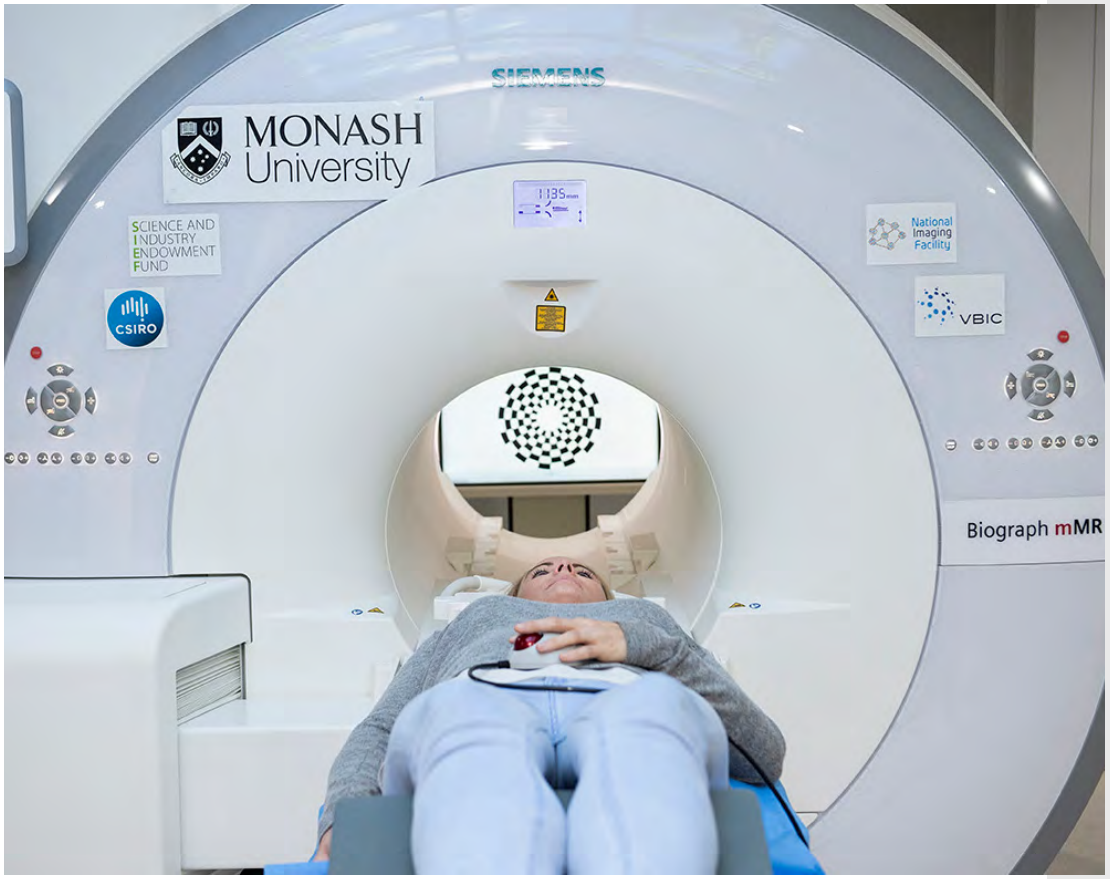
VIEW PAPER ABSTRACT

NEXT STEPS

The team is using the same approach to extract information about brain structure (which is difficult to observe) from brain activity (which is easier to observe), which they hope will enable them to explain a range of other brain phenomena. This approach is like 'hearing' the shape of a drum from the sounds it produces.

Reference:
Robinson, P. A., Pagès, J. C., Gabay, N. C., Babaie, T., & Mukta, K. N. (2018). Neural field theory of perceptual echo and implications for estimating brain connectivity. Physical Review E, 97, 042418. doi: 10.1103/PhysRevE.97.042418

We developed a novel experimental design for measurement of task-evoked changes in regional blood oxygenation and glucose metabolism with high temporal resolution.



BRAIN SYSTEMS

Simultaneous task-based BOLD-fMRI and [18-F] FDG functional PET for measurement of neuronal metabolism in the human visual cortex

Investigators: Gary Egan, Sharna Jamadar, Phillip Ward.

Studies of task-evoked brain activity are the cornerstone of cognitive neuroscience, and unravel the spatial and temporal brain dynamics of cognition in health and disease.

Blood oxygenation level dependent functional magnetic resonance imaging (BOLD-fMRI) is one of the most common methods of studying brain function in humans. BOLD- fMRI indirectly infers neuronal activity from regional changes in blood oxygenation and is not a quantitative metric of brain function.

Regional variation in glucose metabolism, measured using [18-F] fluorodeoxyglucose positron emission tomography (FDG-PET), provides a more direct and interpretable measure of neuronal activity. However, while the temporal resolution of BOLD-fMRI is in the order of seconds, standard FDG-PET protocols provide a static snapshot of glucose metabolism.

We developed a novel experimental design for measurement of task-evoked changes in regional blood oxygenation and glucose metabolism with high temporal resolution.

Over a 90-min simultaneous BOLD-fMRI/FDG- PET scan, [18F] FDG was constantly infused to 10 healthy volunteers, who viewed a flickering checkerboard presented in a hierarchical block design. Dynamic task-related changes in blood oxygenation and glucose metabolism were examined with temporal resolution of 2.5sec and 1-min, respectively. Task-related, temporally coherent brain networks of haemodynamic and metabolic connectivity were maximally related in the visual cortex, as expected.

Our results demonstrate that a hierarchical experimental design, together with the infusion FDG-PET technique, enabled both modalities to track task-related neural responses with high temporal resolution.

The simultaneous MR-PET approach has the potential to provide unique insights into the dynamic haemodynamic and metabolic interactions that underlie cognition in health and disease.

NEXT STEPS

We aim to improve the temporal resolution of the simultaneous BOLD-fMRI/FDG-fPET imaging in addition to investigating normal resting state activity using simultaneous BOLD-fMRI/FDG-fPET. We also hope to characterise the dynamics of brain function and metabolism of cognition in healthy ageing.

BRAIN SYSTEMS

Understanding the neural systems and circuits underlying selective attention in humans and rodents

Investigators: Jason Mattingley, Ehsan Arabzadeh, David Painter, Matthew Tang, Angela Renton, Lisa Wittenhagen, Susan Travis

A central research goal of our work is to understand how attention affects sensory encoding. We have made a number of important discoveries concerning the manner in which simple task goals can affect neural and behavioural responses to sensory events.

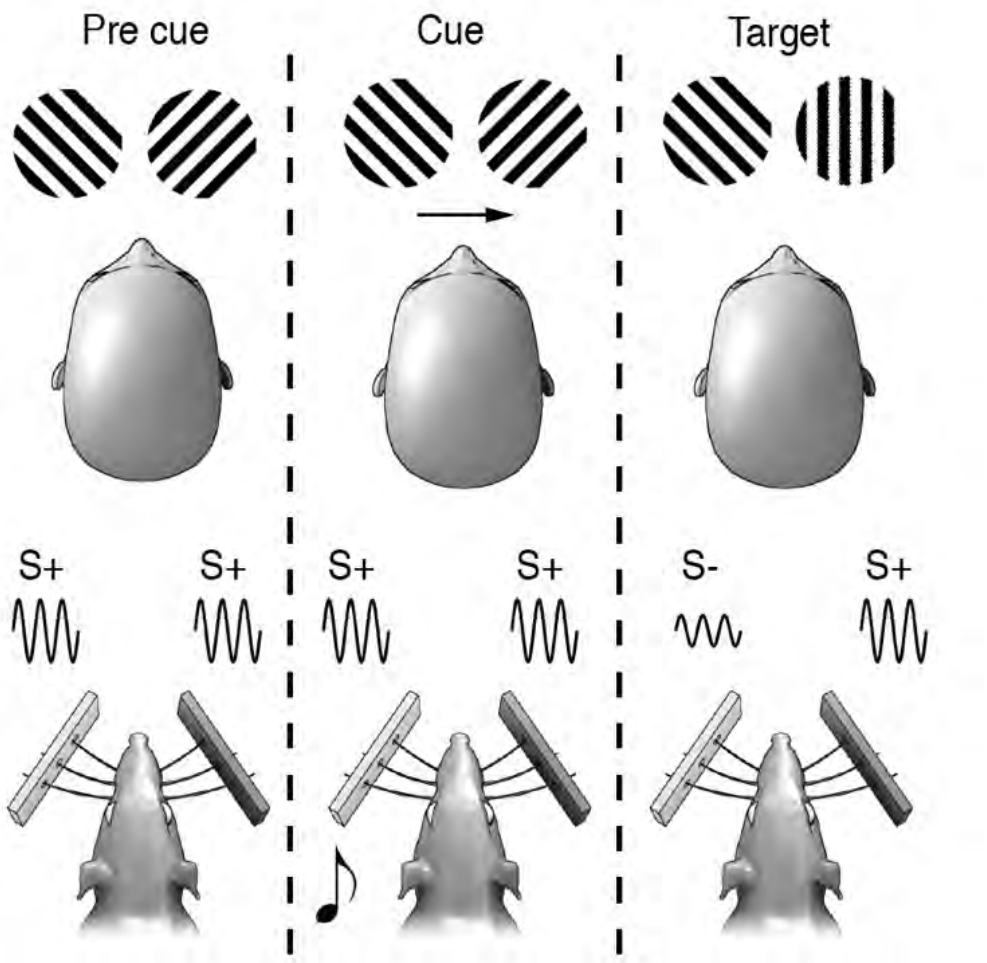
We have also provided important evidence in humans that attention spreads across the visual field to influence the processing of stimuli located outside the current spatial focus of attention. In new work, we are using multivariate analysis approaches, including forward encoding models, to characterise how simple featural information, including orientation, motion and spatial location, is affected by changes in attentional state. Such multivariate approaches quantify how much stimulus-specific information is present in population level neural activity recorded with EEG or fMRI.

We are also seeking to better understand the neuronal mechanisms underlying attention. For example, we are recording activity in mouse cortex in response to visual and whisker stimulation, using two photon calcium imaging and microelectrode recordings.

NEXT STEPS

We aim to develop parallel protocols for use in rodents and humans, and to apply common computational analyses to relate underlying mechanisms of attention at the level of single neurons and whole brain systems.

We are also seeking to better understand the neuronal mechanisms underlying attention.



We have shown that in 600+ people an anatomical subcortical pulvinar amygdala route exists and that it facilitates fear recognition.

BRAIN SYSTEMS

Salient information processing in subcortical and cortical brain pathways

Investigators: Marta Garrido, Jason Mattingley, Pankaj Sah, Nao Tsuchiya, Jessica McFadyen

A decade ago, patient TN became cortically blind after two strokes. His visual cortex was completely destroyed as evident in the MRI and yet, when forced to judge the emotion of faces presented to him, he could do so above chance. This phenomena was coined affective blindsight and a possible explanation was put forward suggesting that an alternative subcortical route bypassing the visual cortex might convey this information to the amygdala, a known emotion centre in the brain.

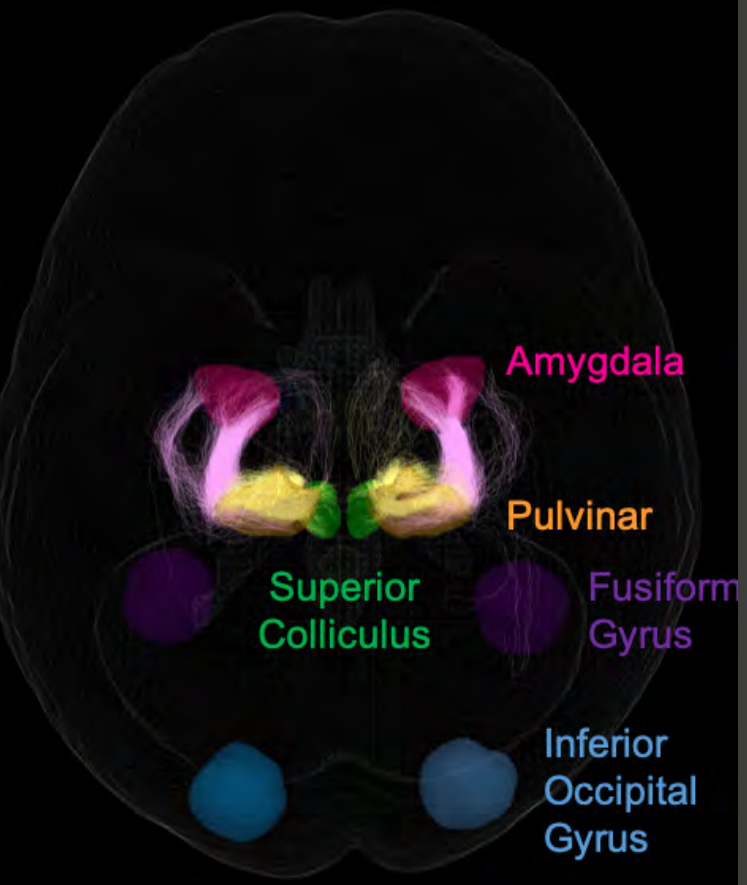
This hypothesis was contentious however as the very existence of this route in humans was yet to be proven, let alone its putative functional role in conveying affective information with bearing on behaviour.

In this project, we have leveraged publicly available MRI data via the Human Connectome Project to show in 600+ people that an anatomical subcortical pulvinar amygdala route exists indeed and it facilitates fear recognition. Moreover, we show that this circuit is functional, such that greater white matter connectivity is correlated with greater functional connectivity between the pulvinar and the amygdala. These findings demonstrate that the brain affords alternative shortcuts which both speed up and ensure redundancy mechanisms for environmental information that is critical for survival, like fear.

Combining neuroimaging (fMRI and DTI), electrophysiological recordings in both humans (EEG and magenetoencephalography (MEG)) and rats (local field potentials (LFP)), as well as computational modelling (Dynamic Causal Modelling – DCM), and machine learning, we are investigating the role of a putative subcortical pathway that links thalamus and amygdala; investigate the white matter connections that enable predictive processes in both self-generated and externally generated stimuli; and develop analytical tools that enable both testing and visualisation of computational models for how we learn about statistical patterns in the environment and make predictions of forthcoming stimuli.

RELATED PUBLICATION

A newly discovered pathway in the brain helps us recognise fearful expressions



PUBLICATION IN A NUTSHELL

A newly discovered pathway in the brain helps us recognise fearful expressions

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

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

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

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

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

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

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

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

VIEW PAPER ABSTRACT

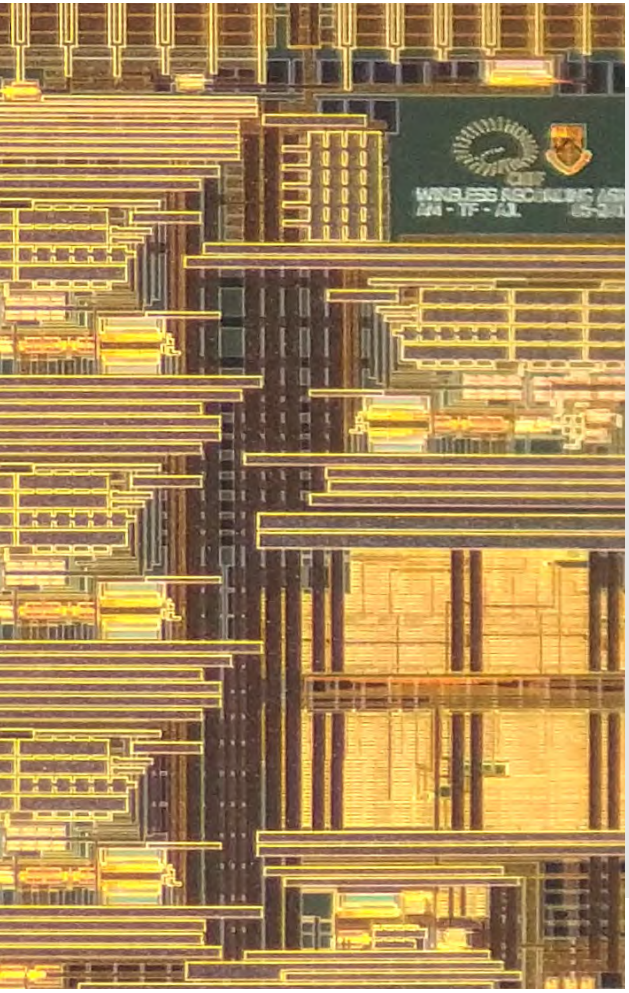
NEXT STEPS

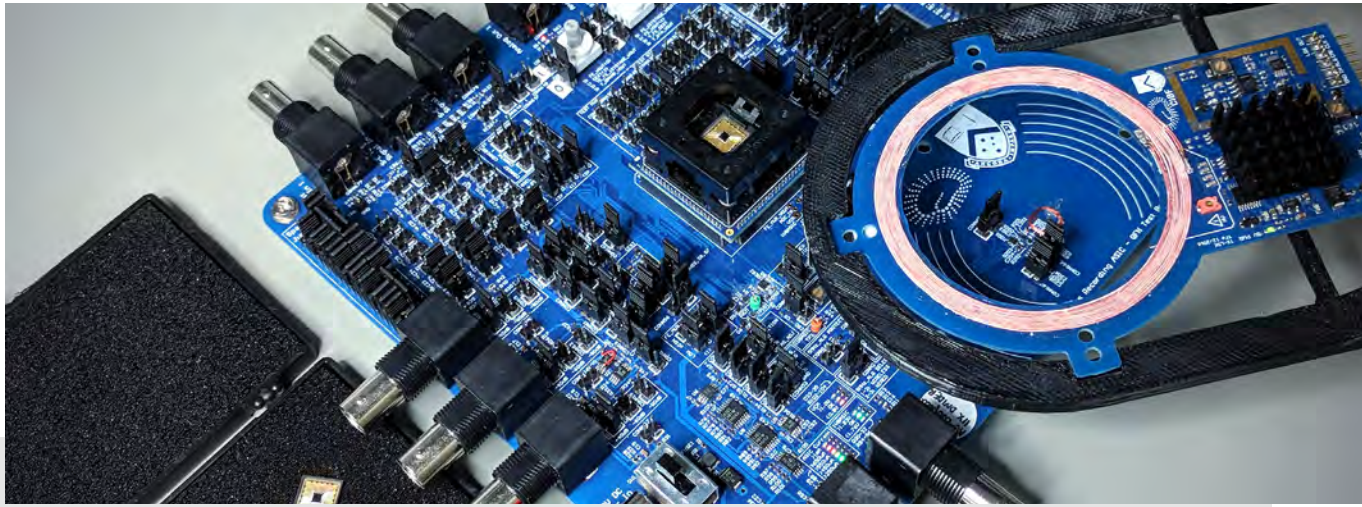
The researchers are studying whether this pathway is involved in sending rapid signals in the brain when we encounter an unexpected threat. They are also using the same experimental approach to study a person with blindsight, to see how the pathway to the amygdala has changed over time.

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

MODELS, TECHNOLOGIES & TECHNIQUES

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





MODELS, TECHNOLOGIES AND TECHNIQUES

Implantable Neuronal Recording Device

Investigators: Arthur Lowery, Anand Mohan, Timothy Feleppa, Yan Wong

We are developing a Wireless Brain Machine Interface (BMI) system which is able to record and interpret neuronal activity. The system records neural activity directly from the brain, in the form of Action Potentials (close to a specific neuron) and Local Field Potentials (an average of several neurons).

An array of microelectrodes, sitting on the back of a 'tile' (a fingernail-sized wireless-connected implant), are used to sense electrical potentials at the implantation site. Our electronic microchip amplifies and digitises these low-level signals, enabling transmission of neural information to the outside world via a wireless link.

Our wireless link is unique in its ability to not only receive information from the tile, but also provide it with the operating power for the electronics within the tile. That is, our system does not require subcutaneous wiring or implanted batteries, so avoids mechanical irritation to the brain, minimising implant size and maximising implant lifespan and safety.

To date, we have developed a prototype version of the system incorporating our low-voltage microchip. Preliminary *in-vivo* testing has been performed in a rodent, which has validated the operation of the wireless inductive link for both power and data transfer and identified signal recording performance criteria which can be improved by a second generation microchip.

NEXT STEPS Work has begun on designing the intricate circuits within a next generation microchip. These will amplify and digitise neural information with increased resolution and processing flexibility, increasing the measurement fidelity.

MODELS, TECHNOLOGIES & TECHNIQUES

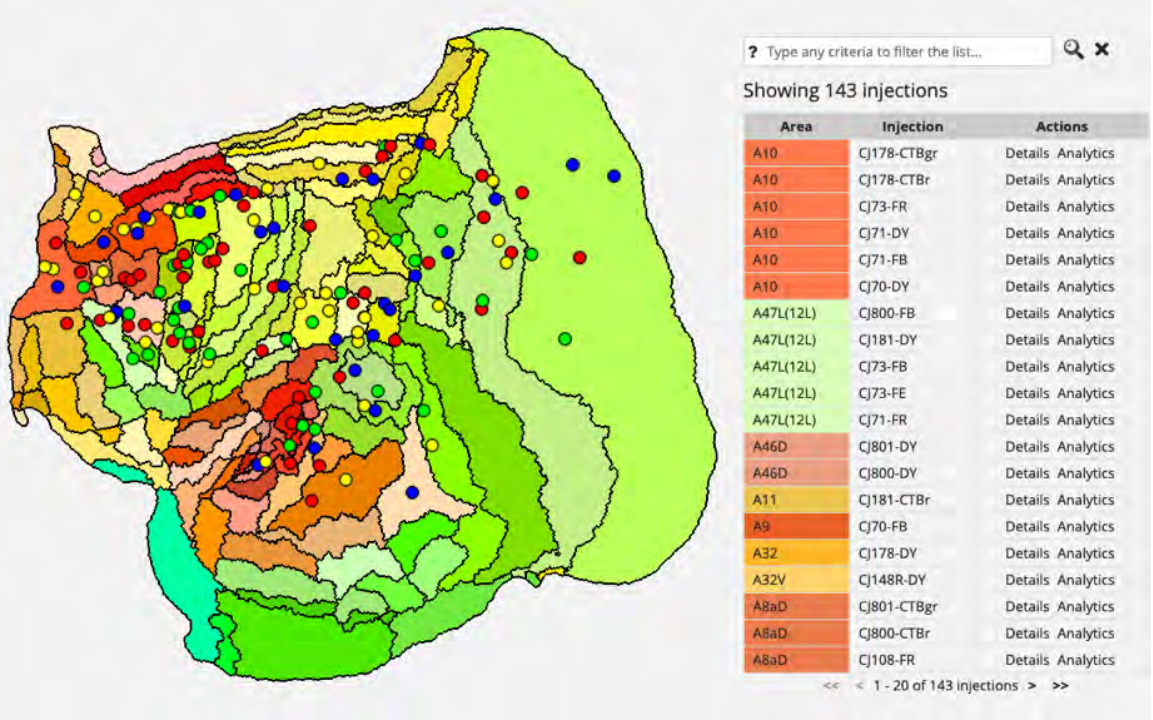
A cellular-scale connectome of the primate brain

Investigators: Marcello Rosa, Partha Mitra, Paul Martin, Ulrike Grunert, Piotr Majka.

Traditional ways of sharing scientific data, such as books and papers, do not allow access to complete data sets, and cannot be updated once published. In essence, each publication represents a summary snapshot of the standard of knowledge at a specific point in time, which is coloured by the authors' interpretations. Internet technologies offer the possibility of sharing complete sets of results from each experiment, including both raw data and interpretations; moreover, these interpretations can be periodically updated to reflect new knowledge. However, these new technologies also raise new challenges in terms of providing vast amounts of data in a way that is easily searchable, navigable, and scientifically accurate.

We are trying to address these challenges in the context of generating a complete map of the connections between areas of the primate cerebral cortex - one of the most complex structures in the body. We have already developed a procedure for registration of neuroanatomical data from hundreds of experiments into a single interface that allows data visualisation in many ways - from focus on the connections of single cells, to 3-D models of the brain.

This interface allows immediate sharing of full data sets through a website, and is being accessed by researchers throughout the world, including forming the basis of published studies. The processing of data for this interface requires several manual steps, which slow the data dissemination. We are currently working on automating these processes using machine learning.

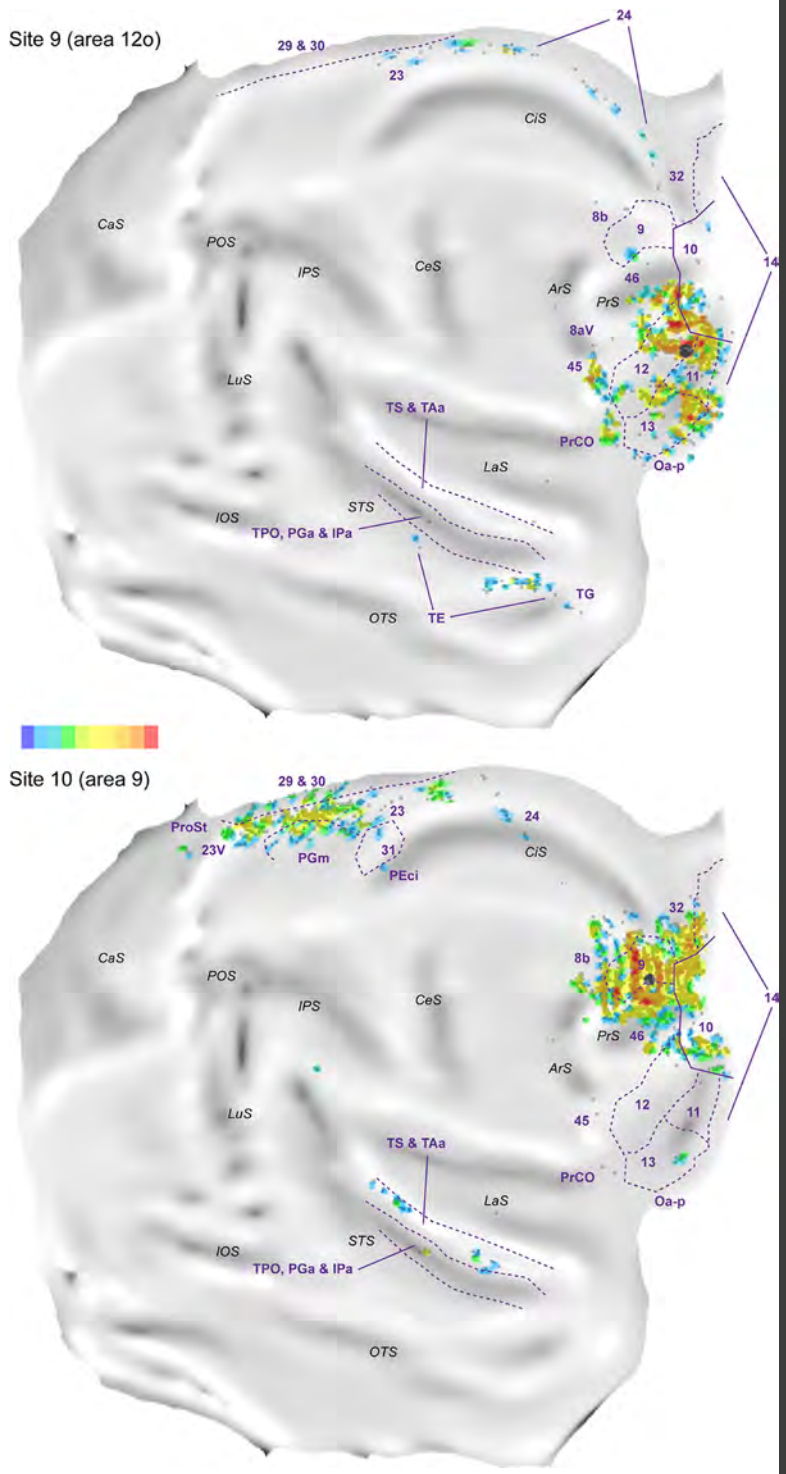


NEXT STEPS

We aim to develop parallel protocols for use in rodents and humans, and to apply common computational analyses to relate underlying mechanisms of attention at the level of single neurons and whole brain systems.

RELATED PUBLICATION

A newly discovered pathway in the brain helps us recognise fearful expressions



PUBLICATION IN A NUTSHELL

Polar expedition: mapping connections at the tip of the brain

Humans are not the only primate species to have subdivisions in the frontopolar cortex.

The ultimate aim of neuroscience is to understand the human brain. When experiments on humans are not possible, researchers rely instead on animal studies. But what can data from these species tell us about the evolution of the human brain?

The frontopolar cortex is a part of the brain found only in primates. In humans, it has subdivisions with different brain connectivity and functions. In non-human primates such as macaques and marmosets, however, no such subdivisions had been found – suggesting that humans were the only species to have undergone this evolutionary change.

Brain Function CoE chief investigator Marcello Rosa, associate investigator Sofia Bakola, and affiliate PhD student Tristan Chaplin from Monash University, in collaboration with researchers in Brazil, Poland and the USA, studied the connections that the frontopolar cortex makes to the rest of the brain in tufted capuchin monkeys.

The capuchin has a similar brain structure to the macaque, but is more closely related genetically to the marmoset. The three species also have different brain sizes: capuchin brains are ten times larger than the marmoset's, but slightly smaller than the macaque's.

The researchers found that brain size is related to the pattern of connections between brain areas: the smaller the brain, the more interconnected the areas become.

They also found that different parts of the frontopolar cortex in the capuchin monkey make distinctive connections with other areas of the brain, hinting at precursors of the subdivisions found in human brains (although these appear to be less distinct). These results suggest that the organisation of the brain's surface is essentially similar across all primates, with the differences in connectivity determined mostly by the number of brain cells.

VIEW PAPER ABSTRACT

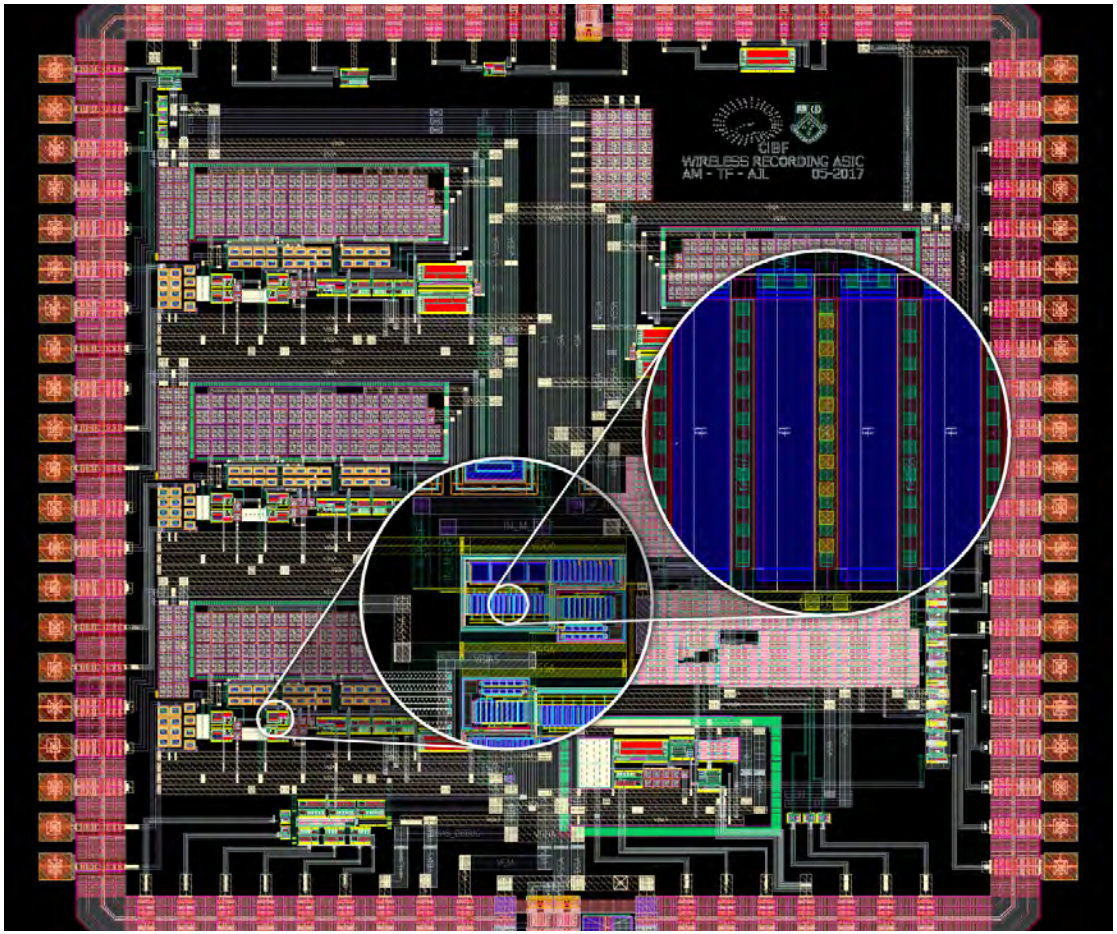
NEXT STEPS

The researchers plan to perform imaging studies in humans, as well as comparative studies in other primates, to understand the exact functions of the frontopolar cortex subdivisions and how they affect the cognitive abilities of different animals.

Reference

Rosa, M. G. P., Soares, J. G. M., Chaplin, T. A., Majka, P., Bakola, S., Phillips, K. A., Reser, D. H., & Gattass, R. (2018). Cortical afferents of area 10 in Cebus monkeys: implications for the evolution of the frontal pole. Cerebral Cortex. doi: 10.1093/cercor/bhy044

Developing novel printable and dissolvable electronics that can conform to individual brain structures and allow recording across a wide area.



MODELS, TECHNOLOGIES & TECHNIQUES

Printable electronics for wide area neural recording

Investigators: Stan Skafidas, Michael Ibbotson, Steve Petrou, Babak Nasr, Gursharan Chana, Basem Hassan.

We are developing novel printable and dissolvable electronics that can conform to individual brain structures and allow recording across a wide area. This technology is aimed at providing Centre researchers with a competitive advantage by enabling recordings of brain activity in awake animals under various experimental paradigms and with minimal disruption to normal brain activity.

We have fabricated inkjet printed thin-film transistors (TFTs) based on biocompatible sodium alginate (NaAlg) electrolyte and metal oxide nanoparticles (NPs) dispersion, termed a nanoink. NaAlg is widely used in the field of drug delivery, and tissue engineering due to its non-toxic, biocompatible nature. Therefore, these devices show great potential as printable and disposable biosensors for diagnostic monitoring of tissues as well as targeted and timed release of therapeutics.

We have also demonstrated construction of fully printed synaptic transistors circuits demonstrating individual iono-neuronal dynamics that can be tuned by varying the width and length of the semiconductor channel. These advances will allow us to emulate specific neuronal sub-types and construct neuronal networks.

Lastly, we have established a reconfigurable silk fibroin memristor based convolution network. These advances provide better alternatives to conventional Von Neumann architecture in pattern-processing applications as they possess brain-like parallel processing capabilities.

MODELS, TECHNOLOGIES & TECHNIQUES

Adaptive optics for lightsheet imaging

Investigators: Steve Petrou, Tim Karle.

Lightsheet imaging uses a thin shaped laser beam to illuminate a narrow plane within a sample. The sample is then stepped through the sheet of light and imaged, quickly building up a picture of an entire three-dimensional volume.

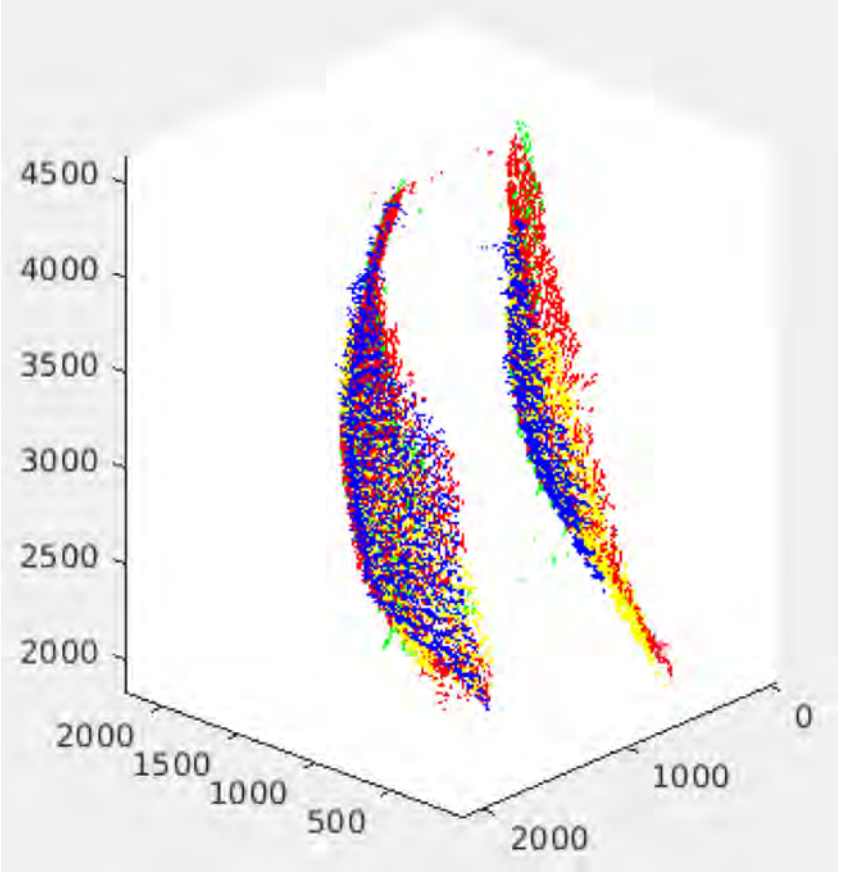
The technique allows us to map large three-dimensional brain samples at very high resolution, in a short amount of time, while preserving the fluorescent labels on various brain structures. This offers a rapid and extremely accurate way of comparing whole brain samples to obtain statistically significant results when analysing complex brain circuitry and modelling brain disease.

Conventional lightsheet microscopes are susceptible to excess background signal generated by neighbouring regions in the sample to those actually being sampled. By carefully synchronising an advanced sCMOS recording camera to a scanning beam, we are aiming to reduce background signal in our lightsheet microscope. This will yield much clearer, higher contrast images of brain tissue.

Furthermore, to optimise image clarity we are iteratively changing the profile of the lightsheet, using adaptive optics, in response to the residual scattering of light in the tissue. This scattering is due to the tiny differences in the refractive index across the sample, which deviate the beam to varying degrees and cause the image to become fuzzy.

NEXT STEPS

We will continue to optimise the equipment and the experimental and processing steps to ensure the best quality outputs.



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Hover over ● for publication highlights

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68. **Saker P, Farrell MJ, Egan GF, et al. Influence of anterior midcingulate cortex on drinking behavior during thirst and following satiation. *Proc Natl Acad Sci USA*. 2018;115(4):786-91.**

69. Sanz-Leon P, Robinson PA, Knock SA, et al. NFTsim: Theory and simulation of multiscale neural field dynamics. *J Comput Biol*. 2018;14(8):e1006387.

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71. Soto-Breceda A, Kameneva T, Meffin H, et al. Irregularly timed electrical impulses reduce adaptation of retinal ganglion cells. *J Neural Eng*. 2018;15(5):056017.

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75. Tang MF, Smout CA, Arabzadeh E, et al. Prediction error and repetition suppression have distinct effects on neural representations of visual information. *eLife*. 2018;7:e33123.

76. van der Groen O, Tang MF, Wenderoth N, et al. Stochastic resonance enhances the rate of evidence accumulation during combined brain stimulation and perceptual decision-making. *PLoS Comput Biol*. 2018;14(7).

77. Verghese A, Mattingley J, Palmer P, et al. From eyes to hands: Transfer of learning in the Simon task across motor effectors. *Atten Percept Psychophys*. 2018;80:193-210.

78. Ward PGD, Ferris NJ, Raniga P, et al. Combining images and anatomical knowledge to improve automated vein segmentation in MRI. *NeuroImage*. 2018;165:294-305.

79. Wilson MT, Fulcher BD, Fung PK, et al. Biophysical modeling of neural plasticity induced by transcranial magnetic stimulation. *Clin Neurophysiol*. 2018;129(6):1230-41.

80. Wong YT, Ahnood A, Maturana MI, et al. Feasibility of nitrogen doped ultrananocystalline diamond microelectrodes for electrophysiology recording from neural tissue. *Front Bioen Biotechnol*. 2018;226:85.

81. Yajadda MMA, Gao X. Effect of Coulomb blockade on the switching time of Ag–Ag2S–Pt atomic switches. *Phys Lett A*. 2018;382(41):3031-4.

82. Yu HH, Atapour N, Chaplin TA, et al. Robust visual responses and normal retinotopy in primate lateral geniculate nucleus following long-term lesions of striate cortex. *J Neurosci*. 2018;38(16):3955-70.

83. Zavitz E, Price NSC. Understanding sensory information processing through simultaneous multi-area population recordings. *Front Neural Circuits*. 2018;12:115.

84. Zeater N, Buzas P, Dreher B, et al. Projections of three subcortical visual centers to marmoset lateral geniculate nucleus. *J Comp Neurol*. 2018;527:535-45.

85. Zhang T, Gillies MC, Madigan MC, et al. Disruption of de novo serine synthesis in Muller cells induced mitochondrial dysfunction and aggravated oxidative damage. *Mol Neurobiol*. 2018;55(8):7025-37.

86. Zobaer MS, Robinson PA, Kerr C. Physiology-based ERPs in normal and abnormal states. *Biol Cybern*. 2018;112(5):465-82.

Presentations

Hover over ● for presentation highlights

International Presentations

1. Arabzadeh E. Information processing in the rodent sensory cortex: population dynamics across behavioural states. Neurons, Synapses & Circuits: From Function to Disease. 16-18 Aug 2018; Sydney, Australia.
2. Dzafic I. The predictive brain in the schizophrenia spectrum. 8th Australasian Cognitive Neuroscience Society Conference. 22-25 Nov 2018; Melbourne, Australia.
3. Dzafic I. Neural dynamics underlying psychotic experiences in healthy people. Australasian Neuroscience Society, 38th Annual Scientific Meeting. 3-6 Dec 2018; Brisbane, Australia.
4. Egan GF. Molecular Imaging-Translational PET/MRI. 12th Congress of the World Federation of Nuclear Medicine and Biology. 20-24 Apr 2018; Melbourne, Australia.
5. Egan GF. Novel approaches for investigating brain function in health and disease using simultaneoud MR-PET imaging. International Society of Neurosciencce Annual Meeting. 16-17 Jun 2018; Kowloon, Hong Kong.
6. Egan GF. Investigating brain function in health and disease using novel simultaneous neurovascular and cerebral metabolism neuroimaging approaches. Monash-Newcastle Neuroscience Symposium. 27 Sep 2018; Kuala Lumpur, Malaysia.
7. Filmer H. For a minute there I lost myself… Dosage-dependent increases in mind wandering with prefrontal tDCS. 8th Australasian Cognitive Neuroscience Society Conference. 22-25 Nov 2018; Melbourne, Australia.
8. Fulcher B. Feature-based time-series analysis. NII Shonan Meeting: Analysing Large Collections of Time Series. 22 Jun 2018; Shonan Village, Japan.
9. Garrido M. Keynote: Shortcuts to the amygdala. 11th Australasian Workshop on Neuro-Engineering and Computational Neuroscience. 27-29 Nov 2018; Sydney, Australia.
10. Garrido M. Dynamic causal modelling. 8th Australasian Cognitive Neuroscience Society Conference. 22-25 Nov 2018; Melbourne, Australia.

11. Garrido M. Garrido, M. 8th Mismatch Negativity Conference MMN2018. 12-15 Jun 2018; Helsinki, Finland.
12. **Garrido M. Young Investigator Award Keynote: The insight of blindsight: Shortcuts to the amygdala. Australasian Neuroscience Society, 38th Annual Scientific Meeting. 3-6 Dec 2018; Brisbane, Australia.**
13. Garrido M. An afferent subcortical white matter pathway to the amygdala facilitates fear recognition. Neurons, Synapses & Circuits: From Function to Disease. 16-18 Aug 2018; Sydney, Australia.
14. Gong P. An integrated model linking structural and dynamical properties of cortical microcircuits. Annual Meeting of the Society for Mathematical Biology 8-12 Jul 2018; Sydney, Australia.
15. Grünert U. Introduction to: 'Retinal architecture and function; new insights'. Annual Meeting of the Association for Research in Vision and Ophthalmology. 29 Apr - 3 May 2018; Honolulu, Hawaii.
16. Grünert U. Nina Kondelos Award Seminar; Visual pathways: from the retina to the brain. Australasian Neuroscience Society, 38th Annual Scientific Meeting. 3-6 Dec 2018; Brisbane, Australia.
17. Harris C. Learning under conditions of uncertainty and threat. Australasian Neuroscience Society, 38th Annual Scientific Meeting. 3-6 Dec 2018; Brisbane, Australia.
18. **Hearne L. Multivariate lesion-network mapping in stroke patients reveals connectivity patterns related to specific and global behavioural deficits. 8th Australasian Cognitive Neuroscience Society Conference. 22-25 Nov 2018; Melbourne, Australia.**
19. Ibbotson MR. Non-linear receptive fields in visual cortex: structure and adaptive characterists. FENS Satellite Meeting: Receptive Fields, Models and Applications. 6 Jul 2018; Berlin, Germany.
20. Lee SCS, Martin PR, Grünert U. Retinal ganglion cell types expressing the transcription factor FoxP2 in primate retina. Annual Meeting of the Association for Research in Vision and Ophthalmology. 29 Apr - 3 May 2018; Honolulu, Hawaii.
21. Lee SCS, Martin PR, Rosa MGP, et al. Multiple types of ganglion cells express the transcription factor SATB1 in marmoset retina. Australasian Neuroscience Society, 38th Annual Scientific Meeting. 3-6 Dec 2018; Brisbane, Australia.
22. Liu Y, Long X, Gong P. Gamma oscillation organize as propagating patterns in cortical circuits. 11th Australasian Workshop on Neuro-Engineering and Computational Neuroscience. 27-29 Nov 2018; Sydney, Australia.
23. Mansouri F. The role of prefrontal cortex in executive control of behaviour. Australasian Neuroscience Society, 38th Annual Scientific Meeting. 3-6 Dec 2018.
24. Mansouri F. The role of prefrontal cortex in cognitive flexibility and control. Japan Cognitive Neuroscience Meeting. 1 Jun 2018; Miura, Japan.
25. Marek R. What the hippocampus tells the prefrontal cortex during extinction. 4th Queensland Brain Institute & Munich Center for neurosciences symposium. 13 Jul 2018; Brisbane, Australia.
26. Martin PR. Receptive field diversity in primate lateral geniculate nucleus. Annual Meeting of the Association for Research in Vision and Ophthalmology. 29 Apr - 3 May 2018; Honolulu, Hawaii.
27. Martin PR. The first steps in visual processing: Retina and subcortical vision, and an introduction to color vision. Machine Intelligence and Brain Research Winter Course/Workshop on Computational Brain Research at IIT Madras. 2-9 Jan 2018; Madras, India.
28. Martin PR, Pietersen ANJ, Eiber CD, et al. Brain-state dependent properties of color-coding cells in marmoset lateral geniculate nucleus. Optical Society of America Fall Vision Meeting. 21-23 Sep 2018; Reno, USA.
29. Masri RA, Martin PR, Grünert U. Topography of cone bipolar cells in human retina. Annual Meeting of the Association for Research in Vision and Ophthalmology. 29 Apr - 3 May 2018; Honolulu, Hawaii.
30. Mattingley J. Bayesian inference as a model of complex perceptual decision making in humans. Australasian Neuroscience Society, 38th Annual Scientific Meeting. 3-6 Dec 2018; Brisbane, Australia.
31. McFadyen J. The influence of prior expectations on conscious face perception depends on emotion 8th Australasian Cognitive Neuroscience Society Conference. 22-25 Nov 2018; Melbourne, Australia.
32. McFadyen J. Expecting the unexpected: Emotional modulation of prediction and conscious awareness. Australasian Neuroscience Society, 38th Annual Scientific Meeting. 3-6 Dec 2018; Brisbane, Australia.
33. Meffin H. The structure of non-linear receptive fields in cat primary cortex. CNS Workshop: Integrative Theories of Cortical Function. 18 Jul 2018; Seattle, USA.
34. Morris A, McFadyen J. Stable population codes for eye position despite unstable tuning of single neurons. Workshop on Sensorimotor Prediction. 1 Oct 2018; Dusseldorf, Germany.

60 International presentations

35. Paxinos G. Brain and mind: who is the puppet and who the puppeteer? 10th International Conference on Vascular Dementia. 22-23 Feb 2018; Paris, France.
36. Paxinos G. Brain and mind: who is the puppet and who the puppeteer? 1st Panhellenic Conference on Neuropsychology. 27-29 Apr 2018; Athens, Greece.
37. Paxinos G. Closing remarks. 23rd Annual Seminar for Continuing Medical Education of Evangelismos Hospital. 14 Mar 2018; Athens, Greece.
38. Paxinos G. The dramatic changes on the planet and the Hellenic roots of ecological ethics. 2nd International Conference, University of Patras. 17-20 Jun 2018; Patras, Greece.
39. Paxinos G. Brain and mind: who is the puppet and who the puppeteer? Genetics, Geriatrics and Neurodegenerative Diseases Research. 25-28 Oct 2018; Toronto, Canada.
40. Petrou S. Channelopathies GOF and LOF in SCN2A. 3rd Dianalund International Conference on Epilepsies. 28-29 Jun 2018; Ringsted, Denmark.
41. Petrou S. Channelopathies GOF and LOF in SCN2A. Channelopathies 2018. 26 Jun 2018; Denver, USA.
42. Pietersen ANJ, Eiber CD, Zeater N, et al. Linear summation of cone inputs to LGN suppressed-by-contrast cells in marmosets. Australasian Neuroscience Society, 38th Annual Scientific Meeting. 3-6 Dec 2018; Brisbane, Australia.
43. Robinson PA. Physical brain dynamics: Activity, structure, and function via neural fields and eigenmodes. 36th SPP Physics Conference 6-9 Jun 2018; Puerto Princesa City, Palawan, Phillipines.
44. Robinson PA. Physical brain connectomics and dynamics. BrainModes. 3-4 Dec 2018; Havana, Cuba.
45. Robinson PA. Nonlinear dynamics In systems neuroscience via neural field theory. The 10th Dynamics Days Asia-Pacific. 1-5 Nov 2018; Xiamen, China.
46. Robinson PA. The physical brain: New approaches to brain structure, activity, and function. The American Physical Society - March Meeting. 5-9 Mar 2018; Los Angeles, USA.
47. Sah P. Probing the eternal sunshine: Memories and fears. 2018 World Science Festival. 21-25 Mar 2018; Brisbane, Australia.
48. Sah P. The amygdala, prefrontal cortex and hippocampal circuit in fear learning. Neurons, Synapses & Circuits: From Function to Disease. 16-18 Aug 2018; Sydney, Australia.
49. Sah P. Partial reinforcement and learning. World Life science Conference Symposium on Multiscale Brainnetome Atlas. 27-29 Oct 2018; Beijing, China.
50. Sanz-Leon P. Low- and high-waking modes in the corticothalamic system. Annual Meeting of the Society for Mathematical Biology 8-12 Jul 2018; Sydney, Australia.
51. Stuart G. Backpropagating action potentials boost dendritic inhibition. European Institute for Theoretical Neuroscience: Dendritic integration and computation with active dendrites. 8-9 Feb 2018; Paris, France.
52. Stuart G. Cellular and circuit mechanisms underlying processing of binocular visual information. Neurons, Synapses & Circuits: From Function to Disease. 16-18 Aug 2018; Sydney, Australia.
53. Tang M. How does prediction affect sensory coding in single neurons and populations? 31st Annual Barrels Meeting. 1-2 Nov 2018; California, USA.
54. Viventi S, Alshawaf A, Farusin S, et al. Developing regenerative therapies for Friedreich's Ataxia using sensory neurons derived from induced pluripotent stem cells. QMB/AWCBR Satellite on Rare Brain Diseases. 30-31 Aug 2018; Queenstown, New Zealand.
55. Wang C. The role of the mPFC and HPC in fear learning and extinction. ELSC Annual Retreat - Kibbutz Ein Gedi. 11-13 Mar 2018; Jerusalem, Israel.
56. Ward PGD. High temporal resolution measurement of brain function and metabolism using simultaneous dynamic PET and functional MR. Australasian Neuroscience Society, 38th Annual Scientific Meeting. 3-6 Dec 2018; Brisbane, Australia.
57. Ward PGD, Sforazzini F, Jamadar SD, et al. Separating BOLD into local and non-local components using a novel simultaneous fMRI-fPET dual analysis. 26th Annual Meeting of the International Society for Magnetic Resonance in Medicine. 16-21 Jun 2018; Paris, France.
58. Yang D-P, Robinson PA. Unified analysis of global and focal aspects of absence epilepsy via neural field theory of corticothalamic system. The 10th Dynamics Days Asia-Pacific. 1-5 Nov 2018; Xiamen, China.
59. avitz E. Sensory and motor processing in cortical circuits in vivo. Australasian Neuroscience Society, 38th Annual Scientific Meeting. 3-6 Dec 2018; Brisbane, Australia.
60. Zavitz E. Naturalistic stimulus structure reveals nonlinear spatial integration in primate V1 and V2. FENS Satellite Meeting: Receptive Fields, Models and Applications. 6 Jul 2018; Berlin, Germany.

47 National presentations

National Presentations

61. Arabzadeh E. Neural coding. Australian Course in Advanced Neuroscience. 8-28 Apr 2018; North Stradbroke Island, Australia.
62. Arabzadeh E. Assessment and ROPES. Brain Function CoE ECR Workshop. 30 Nov - 1 Dec 2018; Brisbane, Australia.
63. Arabzadeh E. Information processing in the rodent sensory cortex: neuronal population dynamics across behavioural states. Neuroscience & Non-Communicable Diseases Seminar Series, University of New South Wales. 12 Oct 2018; Sydney, Australia.
64. Arabzadeh E. Information processing in the rodent sensory cortex: population dynamics across behavioural states. Paint a Great Big Picture: Science Meeting of the Brain Function CoE. 2 Dec 2018; Brisbane, Australia.
65. Dyce G. Frequency tagging in the mouse vibrissal cortex. Brain Function CoE ECR Workshop. 30 Nov - 1 Dec 2018; Brisbane, Australia.
66. Fulcher B. Grant craft tips and tricks. Brain Function CoE ECR Workshop. 30 Nov - 1 Dec 2018; Brisbane, Australia.
67. Garrido M. Career development. Brain Function CoE ECR Workshop. 30 Nov - 1 Dec 2018; Brisbane, Australia.
68. Garrido M. Connectivity mechanisms underpinning learning in the healthy and psychotic brain. Florey Institute of Neuroscience and Mental Health Seminar Series. 17 Jul 2018; Melbourne, Australia.
69. Garrido M. Connectivity mechanisms underpinning learning in the healthy and psychotic brain. The University of Melbourne Seminar Series. 14 Feb 2018; Melbourne, Australia.
70. Gharaei S. In vivo recording techniques. Australian Course in Advanced Neuroscience. 8-28 Apr 2018; North Stradbroke Island, Australia.
71. Gharaei S. Superior colliculus modulates cortical coding of somatosensory information. Brain Function CoE ECR Workshop. 30 Nov - 1 Dec 2018; Brisbane, Australia.
72. Grünert U. Retinal ganglion cells in marmoset. Festschrift, Bogdan Dreher. 12 Jul 2018; Sydney, Australia.
73. Jamadar SD. The first page. Brain Function CoE ECR Workshop. 30 Nov - 1 Dec 2018; Brisbane, Australia.
74. Jamadar SD. Towards multimodal imaging of cognitive reserve: Development of simultaneous MR-PET for the study of cognitive reserve in healthy ageing. Monash Biomedical Imaging Seminar Series. 7 Jun 2018; Melbourne, Australia.
75. Jung YJ. Orientation maps in the primary visual cortex of an Australian marsupial, the Tammar Wallaby Macropus eugenii. Brain Function CoE ECR Workshop. 30 Nov - 1 Dec 2018; Brisbane, Australia.
76. Karle T. Combining light-sheet imaging and molecular profiling to investigate neuron populations in models of genetic epilepsy. Datablitz Epilepsy. 26 May 2018; Melbourne, Australia.
77. Kheradpezhouh E. TRPA1 modulates evoked neuronal responses in mouse somatosensory (barrel) cortex. Brain Function CoE ECR Workshop. 30 Nov - 1 Dec 2018; Brisbane, Australia.
78. Lowery A. Bionic vision: The brain-machine interface. 2018 Joint Lecture with Australian Academy of Technology and Engineering. 12 Jul 2018; Melbourne, Australia.
79. Lowery A. Bionic vision. IEEE Victoria Section, Annual General Meeting. 12 Dec 2018; Melbourne, Australia.
80. Maljevic S. Changing the channel - Genes, mechanisms and targeted therapy in genetic epilepsies. Florey Institute of Neuroscience and Mental Health Seminar Series. 13 Nov 2018; Melbourne, Australia.
81. Mansouri F. The dissociable roles of prefrontal cortical regions in executive control of behaviour. Paint a Great Big Picture: Science Meeting of the Brain Function CoE. 2 Dec 2018; Brisbane, Australia.
82. Martin PR. Bogdan and primate studies. Festschrift, Bogdan Dreher. 12 Jul 2018; Sydney, Australia.
83. McFadyen J. Stable population codes for eye position despite context-dependent tuning of single neuron. Brain Function CoE ECR Workshop. 30 Nov - 1 Dec 2018; Brisbane, Australia.
84. McFadyen J. Shortcuts for fear, conscious perception, and surprise in hierarchical visual systems. QBI Neuroscience Seminar Series. 1 Aug 2018; Brisbane, Australia.
85. Nasr B. Helium ion microscopy orion NanoFab. Helium Ion Microscopy Annual WorkshopHelium Ion Microscopy Annual Workshop. 24-25 Jan 2018; Brisbane, Australia.
86. Nasr B. Biological imaging via helium ion microscopy. Second Postdoctoral Methods Symposium. 13 Sep 2018; Melbourne, Australia.
87. Orchard ER, Ward PGD, Sforazzini F, et al. Does parenthood lead to enduring changes in the human brain. 1st Meeting of the Organisation for Human Brain Mapping Australian Chapter. 12 Oct 2018; Melbourne, Australia.

79 Poster presentations

88. Paxinos G. Is the brain the right size? Brains on the Hill. 26-28 Mar 2018; Canberra, Australia.

89. Paxinos G. Brain and mind: who is the puppet and who the puppeteer? RANZCP 7th Annual Neuropsychiatry and Behavioural Neurology Conference. 23-24 Nov 2018; Melbourne, Australia.

90. Petrou S. Disease mechanism directed therapy in SCN1A/SCN2A. Australian Physiological Society Meeting. 25-28 Nov 2018; Sydney, Australia.

91. Postnova S. Time management and academic/industry balance. Brain Function CoE ECR Workshop. 30 Nov - 1 Dec 2018; Brisbane, Australia.

92. Postnova S. Passenger wellbeing in the air and on the ground: an interdisciplinary approach. Sleep DownUnder 2018. 19 Oct 2018; Brisbane, Australia.

93. Rangelov D. Neural correlates of complex decision-making. Paint a Great Big Picture: Science Meeting of the Brain Function CoE. 2 Dec 2018; Brisbane, Australia.

94. Sah P. The amygdala, prefrontal cortex and hippocampal circuit in fear learning. Seminar Series, School of Medicine, University of Tasmania. 30 Nov 2018; Hobart, Tasmania.

95. Sanz-Leon P. Science communication. Brain Function CoE ECR Workshop. 30 Nov - 1 Dec 2018; Brisbane, Australia.

96. Singh T. Implementing a Behavioural Paradigm with Two-Photon Calcium Imaging to probe Bilateral Integration in Head-fixed mice. Brain Function CoE ECR Workshop. 30 Nov - 1 Dec 2018; Brisbane, Australia.

97. Stuart G. The electrical structure of neurons. Australian Course in Advanced Neuroscience. 8-28 Apr 2018; North Stradbroke Island, Australia.

98. Stuart G. Cellular and circuit mechanisms underlying binocular vision. Paint a Great Big Picture: Science Meeting of the Brain Function CoE. 2 Dec 2018; Brisbane, Australia.

99. Sun SH. Extracellular spike waveform predicts whether single units recorded in visual cortex are tuned to orientation. Brain Function CoE ECR Workshop. 30 Nov - 1 Dec 2018; Brisbane, Australia.

100. Viventi S, Frausin S, Alshawaf A, et al. Developing regenerative therapies for Friedreich's Ataxia using sensory neurons derived from induced pluripotent stem cells. 13th Annual Fiedreich Ataxia Scientific Symposium. 25 Oct 2018; Melbourne, Australia.

101. Wang C. Neural activity in the medial prefrontal cortex and hippocampus that encodes novel object recognition. Brain Function CoE ECR Workshop. 30 Nov - 1 Dec 2018; Brisbane, Australia.

102. Ward PGD. Neuroimaging of cerebral physiology: Deconvolving the neurological from the vascular. Monash Biomedical Imaging Seminar Series. 13 Sep 2018; Melbourne, Australia.

103. Ward PGD, Harding IH, Raniga P, et al. Disease stage-dependent longitudinal progression of dentate nucleus iron and volume changes in Friedreich ataxia: The IMAGE-FRDA study. 13th Annual Fiedreich Ataxia Scientific Symposium. 25 Oct 2018; Melbourne, Australia.

104. Ward PGD, Sforazzini F, Jamadar SD, et al. Separating the neuronal and vascular contributions to the BOLD signal using simultaneous MR-PET. 1st Meeting of the Organisation for Human Brain Mapping Australian Chapter. 12 Oct 2018; Melbourne, Australia.

105. Yunzab M. How to become a Neurodetective: Developing an innovate neural recording device. Brain Function CoE ECR Retreat. 4-5 Aug 2018; Melbourne, Australia.

106. Yunzab M. Revisiting the bimodal classification of cells in primary visual cortex. Brain Function CoE ECR Workshop. 30 Nov - 1 Dec 2018; Brisbane, Australia.

107. Zeater N. Binocularity in the LGN of the marmoset. Festschrift, Bogdan Dreher. 12 Jul 2018; Sydney, Australia.

Poster Presentations

108. **Almasi A, Meffin H, Cloherty SL, et al. How cells in primary visual cortex combine features to attain selectivity and invariance for object recognition. 11th Australasian Workshop on Neuro-Engineering and Computational Neuroscience. 27-29 Nov 2018; Sydney, Australia.**

109. Baran J, Chen Z, Sforazzini F, et al. SPM-based segmentation of air in the human head for improved PET attenuation correction in simultaneous PET/MR. 26th Annual Meeting of the International Society for Magnetic Resonance in Medicine. 16-21 Jun 2018; Paris, France.

110. Baran J, Pawar K, Ferris N, et al. Accurate attenuation correction for simultaneous PET/MR based on a deep learning segmentation method. 12th Congress of the World Federation of Nuclear Medicine and Biology. 20-24 Apr 2018; Melbourne, Australia.

111. Belluccini EA, Martin PR, Zeater N, et al. Binocular interaction in the marmoset lateral geniculate nucleus. Australasian Neuroscience Society, 38th Annual Scientific Meeting. 3-6 Dec 2018; Brisbane, Australia.

112. Chandra A, Lee SCS, Masri RA, et al. Melanopsin containing ganglion cells and displaced cholinergic amacrine cells in human retina express calbindin. Annual Meeting of the Association for Research in Vision and Ophthalmology. 29 Apr - 3 May 2018; Honolulu, Hawaii.

113. Chen G, Gong P. Computing by modulating onging coherent patterns: A mechanism of active perception. 11th Australasian Workshop on Neuro-Engineering and Computational Neuroscience. 27-29 Nov 2018; Sydney, Australia.

114. Chen G, Gong P. Computing by modulating spontaneous activity patterns: A dynamical mechanism of active cortical processing. Computing by modulating spontaneous activity patterns: A dynamical mechanism of active cortical processing. 25-28 Sep 2018; Berlin, Germany.

115. Close T, Ward PGD, Sforazzini F, et al. NeuroImaging Analysis (NiAnalysis): Python package for archive-centric analysis of neuroimaging data. 24th Annual Meeting of the Organisation for Human Brain Mapping. 17-21 Jun 2018; Singapore, Singapore.

116. Deeba F, Sanz-Leon P, Robinson PA. Effects of physiological parameter evolution on tonic-clonic seizure. Society for Mathematical Biology Meeting 2018. 8-12 Jul 2018; Sydney, Australia.

117. Deerasooriya Y. An efficient neural conductance modelling approach using dynamic action potental clamp data. 27th Annual Computational Neuroscience Meeting. 13-18 Jul 2018; Seattle, USA.

118. Eiber CD, Pietersen ANJ, Zeater N, et al. Visual stimulus specificity of local field potentials in the primate lateral geniculate nucleus (LGN). Australasian Neuroscience Society, 38th Annual Scientific Meeting. 3-6 Dec 2018; Brisbane, Australia.

119. Ferdousi M, Babaie T, Robinson PA. Nonlinear wave interactions in the corticothalamic system. 11th Australasian Workshop on Neuro-Engineering and Computational Neuroscience. 27-29 Nov 2018; Sydney, Australia.

120. Furlong T, Paxinos G. Accelerated habitual behaviour resulting from L-dopa exposure is prevented by N-acetylcysteine. 11th Federation of Europearn Neuroscience Societies Forum of Neuroscience. 7-11 Jul 2018; Berlin, Germany.

121. Gao D. Statistical properties of strengths of structural and functional connectivity. 27th Annual Computational Neuroscience Meeting. 13-18 Jul 2018; Seattle, USA.

122. Gong P, Gu Y. An integrated model linking structural and dynamical properties of cortical microcircuits. Neuroscience 2018: Society for Neuroscience 48th Annual Meeting. San Diego, USA 2018; San Diego, USA.

123. Grünert U, Lee SCS, Kwan WC, et al. Morphological types of retinal ganglion cell projecting to superior colliculus, pulvinar and pretectum in the marmoset. Federation of American Societies for Experimental Biology 24-29 Jun 2018; Olean, USA.

124. Harris C. Learning under conditions of uncertainty and threat. 8th Australasian Cognitive Neuroscience Society Conference`. 22-25 Nov 2018; Melbourne, Australia.

125. Harris C. Learning under conditions of uncertainty and threat. Australasian Neuroscience Society, 38th Annual Scientific Meeting. 3-6 Dec 2018; Brisbane, Australia.

126. Jamadar SD, Sforazzini F, Baran J, et al. Simultaneous BOLD-fMRI and FDG-fPET distinguishes neural and vascular components of brain activity. 24th Annual Meeting of the Organisation for Human Brain Mapping. 17-21 Jun 2018; Singapore, Singapore.

127. **Jia L. In vitro neuronal network models of SCN2A epileptic encephalopathy. Neuroscience 2018: Society for Neuroscience 48th Annual Meeting. 3-7 Nov 2018; San Diego, USA.**

128. Jung YJ, Yunzab M, Almasi A, et al. Orientation maps in the primary visual cortex of an Australian marsupial, the Tammar Wallaby Macropus eugenii. Australasian Neuroscience Society, 38th Annual Scientific Meeting. 3-6 Dec 2018; Brisbane, Australia.

129. Karle T. Combining light-sheet imaging and molecular profiling to investigate neuron populations in models of genetic epilepsy. Datablitz Epilepsy. 26 May 2018; Melbourne, Australia.

130. Li S, Jamadar SD, Sforazzini F, et al. Simultaneous BOLD-fMRI/FDG-PET study of resting state glucose utilization networks in healthy humans. 24th Annual Meeting of the Organisation for Human Brain Mapping. 17-21 Jun 2018; Singapore, Singapore.

131. Li S, Jamadar SD, Ward PGD, et al. Improved dynamic PET reconstruction using temporal decoding. 2018 IEEE Nuclear Science Symposium and Medical Imaging Conference. 10-17 Nov 2018; Sydney, Australia.

132. Li S, Sforazzini F, Jamadar S, et al. Estimation of simultaneous BOLD and dynamic FDG metabolism activation using a coherent ICA method. 26th Annual Meeting of the International Society for Magnetic Resonance in Medicine. 16-21 Jun 2018; Paris, France.

133. Li S, Sforazzini F, Jamadar S, et al. Independent component analysis of functional PET. 12th Congress of the World Federation of Nuclear Medicine and Biology. 20-24 Apr 2018; Melbourne, Australia.

134. Li S, Sforazzini F, Jamadar S, et al. Independent component analysis of task-specific functional PET using a continuous infusion FDG protocol. 24th Annual Meeting of the Organisation for Human Brain Mapping. 17-21 Jun 2018; Singapore, Singapore.

135. Liam Y, Meffin H, Grayden DB, et al. A biologically plausible neural model of visual pathways based on efficient coding. 27th Annual Computational Neuroscience Meeting. 13-18 Jul 2018; Seattle, USA.

136. Liu Y, Gong P. Gamma oscillations organize as propagating patters in cortical circuits. Bernstein Conference 2018. 25-28 Sep 2018; Berlin, Germany.

137. Liu Y., Long X, Gong P. Gamma oscillation organize as propagating patterns in cortical circuits. 11th Australasian Workshop on Neuro-Engineering and Computational Neuroscience. 27-29 Nov 2018; Sydney, Australia.

138. Maljevic S. Mouse model of progressive myoclonic epilepsy. 11th Federation of Europearn Neuroscience Societies Forum of Neuroscience. 7-11 Jul 2018; Berlin, Germany.

139. Marek P. Balanced prefrontal activity controls the expression of emotional memories. Neurons, Synapses & Circuits: From Function to Disease. 16-18 Aug 2018; Sydney, Australia.

140. Masri RA, Lee SCS, Madigan MC, et al. Particle-mediated gene transfection of ganglion cells in human retina`. Australasian Neuroscience Society, 38th Annual Scientific Meeting. 3-6 Dec 2018; Brisbane, Australia.

141. Mattei C, Lim R, Drury H, et al. Generation of inner ear organoids enriched with mchanosensitive vestibular hair cells derived from human pluripotent stem cells. International Society for Stem Cell Research Annual Meeting. 20-23 Jun 2018; Melbourne, Australia.

142. McIntyre M. Temporal order biases behavioural and neural measures of stimulus encoding in a complex perceptual decision-making task. 8th Australasian Cognitive Neuroscience Society Conference. 22-25 Nov 2018; Melbourne, Australia.

143. Menezes de Oliveira M, Pang J, Robinson PA, et al. Feasibility of detecting ocular dominance and orientation preference columns in human visual cortex via fMRI. 11th Australasian Workshop on Neuro-Engineering and Computational Neuroscience. 27-29 Nov 2018; Sydney, Australia.

144. Monfared O, Burkitt AN, Grayden DB, et al. Modelling the electrical impedence of neural tissue based on its cellular building blocks. 27th Annual Computational Neuroscience Meeting. 13-18 Jul 2018; Seattle, USA.

145. Mukta KN, Gao X, Robinson PA. Evoked response potential in a spherical geometry via neural field theory`. 11th Australasian Workshop on Neuro-Engineering and Computational Neuroscience. 27-29 Nov 2018; Sydney, Australia.

146. Mukta KN, Gao X, Robinson PA. Brain activity in a spherical geometry via neural field theory. 27th Annual Computational Neuroscience Meeting. 13-18 Jul 2018; Seattle, USA.

147. Muller EJ, Robinson PA. Suppression of parkinsonian beta oscillations by deep brain stimulation: Comparison of effective protocols. 11th Australasian Workshop on Neuro-Engineering and Computational Neuroscience. 27-29 Nov 2018; Sydney, Australia.

148. Munn BR, Zeater N, Martin PR, et al. Fractal firing rate fluctuations, diverse population coupling and their relations in neural spiking activity. 11th Australasian Workshop on Neuro-Engineering and Computational Neuroscience. 27-29 Nov 2018; Sydney, Australia.

149. Nasir-Ahmad S, Lee SCS, Mansouri FA, et al. Characterisation of ganglion cells in the macaque retina expressing the transcription factor SATB2. Australasian Neuroscience Society, 38th Annual Scientific Meeting. 3-6 Dec 2018; Brisbane, Australia.

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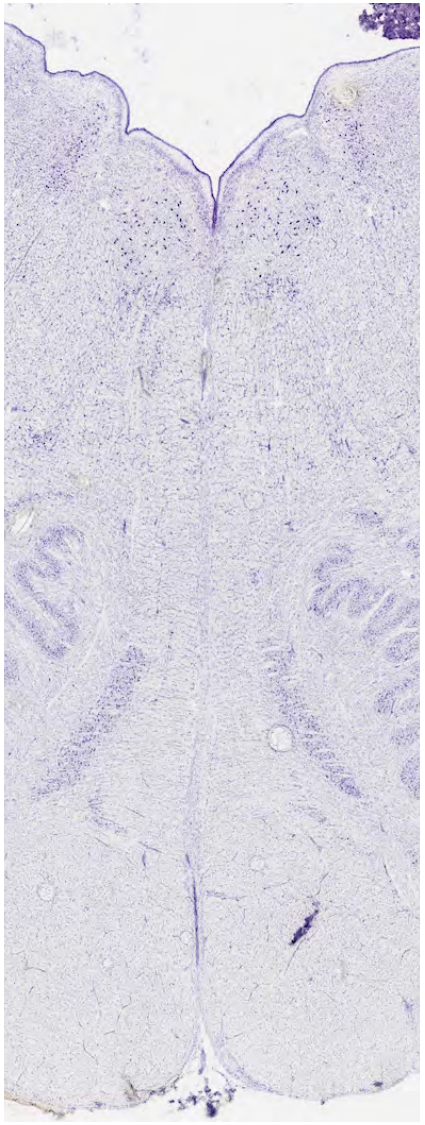


RESEARCH PLANS FOR 2019

Cells and Synapses Theme

- Investigate how visual feature selectivity and invariance arises through the cortical hierarchy.
- Investigate the influence of stimulus history on the nonlinear processing in cortical areas V2 and V4, to understand how the entire visual pathway adapts.
- Investigate how visual feature selectivity and invariance arises through the cortical hierarchy
- Identify functional variability in retinal ganglion cells.
- Further understand the generality of orientation map formation.
- Further assessment of the role of recurrent neural circuits in visual processing, including predictive coding.

Networks and Circuits Theme

- Further investigate neural activity within and across fear-related brain structures during learning by:
    - » Updating and expanding the system for recording neuronal activity during auditory fear-conditioning in a rodent model to include more units from multiple new sites
    - » Using single unit and field potential recordings from the same structures in awake behaving animals, to understand neural activity within and across fear-related brain structures during learning.
- Better understand the principles of how electrical signalling and brain pH change neuronal networks and consequent behaviour in freely moving animals.
- Further investigate corticothalamic interactions of attention-related activity using expanded array electrodes, to study laminar distribution of synchronised activity relative to visual thalamus activity.

Brain Systems Theme

- Use computational modelling approaches to relate patterns of neural activity at the level of single neurons and wider networks, across tasks and species, to develop an integrative framework for understanding predictive coding in the mammalian brain.
- Develop parallel protocols in rodents and humans for investigation of the neural circuits underlying selective attention.
- Develop a complex perceptual decision task that can be accomplished by awake behaving monkeys to investigate perceptual decision making.
- Identify the types of cells within the prefrontal cortex that are active when rats are exploring a novel object.
- Apply neural field theory modelling of brain dynamics to the control of abnormal brain rhythms.
- Further develop techniques for deconstruction blood oxygen level-dependent functional magnetic resonance imaging (fMRI BOLD) signal into local (neuronal) and non-local (haemodynamic) components, to allow routine acquisition and reconstruction of fMRI time-series providing purely local neuronal tissue response to subject visual tasks.

Models, Technologies and Techniques Theme

- Increase the complexity of DAPC analysis by incorporate larger scale neuronal models with more biological realistic structure and function.
- Optimise adaptive optics, objective lens and light sheet imaging hardware, processing and analysis technologies and techniques.
- Apply devices developed for real-time characterisation of electrical and biochemical signals from neurons to neuronal functioning in the context of pathology.
- Apply Neural Field Theory to understand and optimise brain stimulation methods and to track brain states, with applications in study of controlling abnormal brain rhythms.

Centre programs

Centre Fellow Sharna Jamadar and Scholar Edwina Orchard reviewing fMRI data.

Early Career Researchers

Developing outstanding investigators

An important focus of the Centre is to train the next generation of multi-disciplinary Australian leaders in brain research.

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

Our ECR program aims to provide a network of support to enhance their career progression through professional development and mentorship opportunities, as well as providing funding opportunities for conference travel, living allowances for lab exchanges, funding for collaborative experiments, as well as scholarship top-ups and salary supplements.

Each year, the program is primarily driven by the ECR Executive Committee, consisting of elected representatives from each state who plan activities and determine how to best utilise ECR funding for maximum benefit to the whole cohort, attending monthly meetings to achieve these goals.

The 2018 ECR Executive Committee comprised Dr Phillip Ward (VIC), Dr Paula Sanz-Leon (NSW), Dr Ehsan Kheradpezhouh (ACT) and Dr Roger Marek (QLD) (pictured right).

Mid-year retreat

The mid-year retreat took place in Melbourne in August, and attracted 57 ECRs, which was approximately double that of previous years.

Over two days the scientific breadth of the Centre was on display, with more than 40 presentations from ECRs on their projects and their technical expertise. Professional development sessions then followed, which incorporated guidance on attaining research funding, handling biases, industry engagement and entrepreneurship. These sessions were offered by a series of in-house experts (including Centre Associate Investigator Dr Nic Price and Gender, Equity and Diversity Coordinator Prof Melinda Fitzgerald), as well as external professionals (Peter Binks, Business/Higher Education Round Table and Amir Eldad, A2E Partners). The retreat wound down with a series of informal networking opportunities, allowing all attendees to discuss ideas and opportunities in a relaxed setting.

End of year workshop

Taking place as part of the Centre's AGM and Science meeting, the ECR Executive committee hosted their annual workshop. This two-day event was again designed to provide professional development opportunities, on top of sharing scientific updates.

The workshop attracted over 50 registrants who were presented with a series of deep science talks given by Fellows and Scholars based on current research being undertaken as part of the Centre's research program. This was followed by a series of education sessions on grant crafting; comprising first-page hooks, tips and tricks, assessments and ROPES and project management. Day two of the workshop saw additional career development sessions based on effective scientific communication and transferrable skills for careers beyond academia. In addition to professional development, support was offered to the ECR cohort by implementing sessions on wellbeing, ultimately aimed at career longevity. This was a new addition to the workshop in 2018, and came as a direct result of feedback from ECRs. Some topics covered included time-management, career balance, managing an academic career as well as juggling family and caring responsibilities.

To ensure the Centre continues to support its young researchers appropriately and that the ECR program reflects their career development needs and preferences, all ECRs were asked to complete surveys following each event, the results of which inform planning for future initiatives.

Clockwise from top: CIBF ECR retreat; ECRs at AGM dinner; ECRs at AGM dinner; ECRs at AGM dinner, ECR Executive Committee

Future Leaders Accelerator Program

To address the gaps in cross-institutional collaborations and industry engagement for the Centre's early career researchers, the ECR Executive committee established the Future Leaders Accelerator Program in 2018. The program incorporated a series of grantcraft workshops (held during the end-of-year workshop), covering all aspects of planning, drafting, polishing and managing grant applications.

Following on from the theoretical component, ECRs were given the opportunity to present their research ideas to the Centre's CIs, AIs, PIs and Board members in attendance at the Dinner event of the Centre's AGM. Seven ECRs chose to compete in a 3-Minute Fellowship competition. A judging panel awarded cash prizes for first, second and third place winners, with an additional People's Choice prize voted on by all in attendance. Beyond the immediate cash prizes, winners were awarded seed funding for pilot data towards their fellowship applications.

Centre Fellow Dr Paula Sanz-Leon (USyd/ QIMR) took out both first place and the People's Choice award, with second place awarded to Dr Phillip Ward (Monash) and third place to Dr Johan van der Meer (QIMR).

ECR Travel Awards

The ECR Executive Committee organised two rounds of travel awards during 2018, funds of which facilitated travel that benefited ECRs' research and/or careers. Applications were competitively judged, and a total of 16 ECRs were awarded over $9,000 collectively to travel to international and national conferences.

Centre Director Prof Gary Egan presenting Dr Paula Sanz-Leon with her award as the inaugural winner of the 3-Minute Fellowship at the Centre's Annual Dinner in Brisbane, December 2018.

Education

Secondary schools

Australian and New Zealand Brain Bee Challenge

In 2017, the Centre was granted hosting responsibility of the Australian and New Zealand Brain Bee Challenge, coordinated centrally by Centre AI Professor Ramesh Rajan.

The Brain Bee Challenge is an annual neuroscience competition for students in Year 10 in Australia and in Year 11 in New Zealand, which encourages students to learn about the brain, aiming to inspire students to pursue brain-related careers in medicine and research.

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

As in previous years, the national finals were extremely competitive, with Silas Hansch-Maher from SA (Saint Ignatius College) taking out the Australian competition, and Jennifer Mai from QLD (Brisbane State High School) awarded runner-up. The New Zealand winner was Sophia Ye from the North Island (ACG Parnell College) and coming in as very close runner-up was South Island's Ella Taylor (Nelson College for Girls).

Both National winners will be flown to Daegu, South Korea, to compete internationally in the Brain Bee World Championship, which is taking place on 19-21 September 2019, in conjunction with the International Brain Research Organization World Congress.


L-R: Australian winner Silas Hansch-Maher being awarded the perpetual trophy by ANS director Linda Richards; Guest speaker Professor Emeritus Alan Mackay-Sim; Students competing at the national Brain Bee Challenge in Brisbane; Students competing at the national Brain Bee Challenge in Brisbane

Secondary Student Mentoring

In more localised mentoring opportunities, several of the Centre's nodes have opened their doors to Year 10 work experience students, testing their skills and knowledge in real-world employment settings. These students were given an unprecedented opportunity to see what a career as a brain researcher can entail, as well as chat one-on-one with researchers about potential career prospects and how to best achieve them.

In addition, a number of our Melbourne based ECRs took part in the BrainSTEM Innovation Challenge, which offered secondary students the opportunity to work in a research environment and participate in the journey of scientific discovery side-by-side with their STEM mentor. As mentors, our ECRs met with their student groups fortnightly, and helped guide them through experimental design, research fundamentals and presentation of results. After completing the 12-week program, each team had the opportunity to present their results at a public event held at Swinburne University.

Primary schools drawing competition

The Centre continued its successful brain inspired drawing competition as part of Brain Awareness Week, 12–18 March 2018. Brain Awareness Week is a global campaign, led by The Dana Foundation, which aims to increase awareness of the importance and current state of brain research in the world.

We invited primary school students from around Australia to create either a drawing or a creative writing piece, inspired by the thought: "What makes 'sense' in the brain…". We received over 200 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, prior to opening voting to all Centre members. Over 90 Centre staff and students voted for their favourite drawings, awarding 1st, 2nd and 3rd prizes in each category.

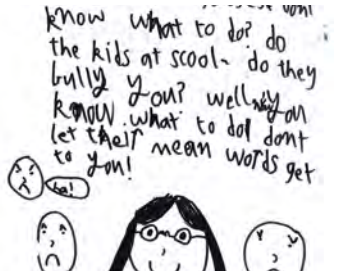
All winners each received a prize pack containing brain-related books, activities, puzzles and games, with each winner's school receiving a brain-related resource pack and a voucher to purchase additional educational resources.

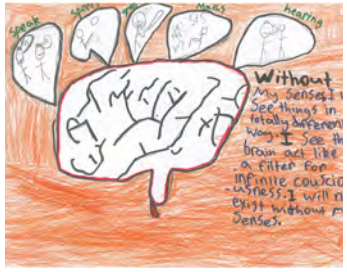
The 1st place winners were treated to a special visit by Centre researchers to award their prizes in person, in addition, giving a fun and interactive presentation to the winner's class.

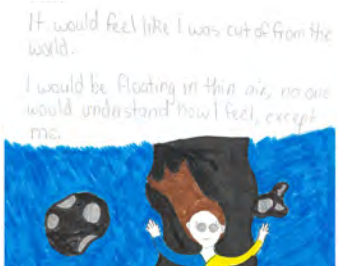
The student artworks have been so well received that many have been placed on display around the Centre Nodes, as well as (with permission) being utilised for our promotional material. Expanding on this opportunity with the aim of sharing our resources with the general public, a selection of these works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

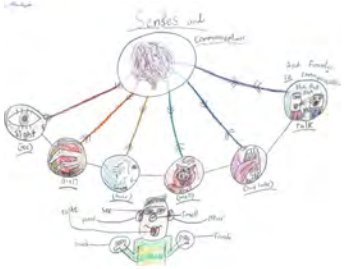
Pictured above left: Centre Fellow Teri Furlong (UNSW) and Centre Affiliate Fellow Sam Merlin (Western Sydney University) at a public library exhibition of student artworks arising from the Centre's primary school drawing competition.

We invited primary school students from around Australia to create either a drawing or a creative writing piece, inspired by the thought: "What makes 'sense' in the brain…".









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 end-users.

This is achieved by engaging with:

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

27 27 plain-language summaries which were shared across all our social media platforms

3,200+ Followers across Facebook and Twitter

From L-R: Lynn Malcolm, Prof Eric Racine, Dr Hannah Maslen, Prof Jeffrey Rosenfeld and DrIsabell Kiral-Kornek were guest speakers at the Brave New Brains event.

The Brain Dialogue

Connecting communities and sharing knowledge

Plain language summaries

One major activity of the Brain Dialogue is to share the Centre's research with the public in a comprehensible format, to ensure everyone can access and benefit from our findings. Our Discovery section presents Centre research outcomes 'In A Nutshell', that explain the paper and its significance in plain English; and 'Next Steps' to encourage further exploration. Communicating our research in this way not only informs the broader community as to what the Centre does, but also opens up opportunities for interdisciplinary research and linkage within the scientific community and industry.

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

In 2018, we wrote and published a total of 27 plain-language summaries which were shared across all our social media platforms. This not only enhanced the reach of our findings, but also increased altmetrics for our researchers leading to additional republication through social media channels.

Together, the summaries of Centre research on the Brain Dialogue website received over 4500 visits in 2018. We also worked with the Altmetric team to include the Brain Dialogue's website feed in their database, and have seen great improvements in the scores for Centre publications with plain-language summaries. A collection of these summaries were republished as a booklet, which has seen over 1000 copies distributed free to the public to further broaden the Centre's communication of its research findings.

Social media

An integrated web and social media presence allows the public unrestricted use and reuse of the research contents, maximising the impact of our resources. The program establishes new and strengthen existing connections between users of the Centre's research outputs, creates opportunities for new interdisciplinary research, and provides linkages to the broader scientific community and industry both Australian wide and globally.

The Brain Dialogue Facebook page provides followers with curated content about new discoveries in brain research from the Centre, as well as the world's top journals and news outlets, and now reaches over 2,400 followers. In 2018, the Brain Dialogue's Twitter feed increased its followers to over 860 across the globe, including research institutions, med-tech organisations, women-in-science groups, journalists and, importantly, neuroscientists.

With all content published using the COPE (Create Once, Publish Everywhere) strategy, the Centre has been capable of reaching over 100,000 Facebook and Twitter users, ensuring content is disseminated widely across the public and scientific communities.

The Brain Dialogue aims to maximise the social, economic and scientific benefits of brain research.

Neuroethics

Our Neuroethics program continues to grow with a year packed with national and international engagement and outreach activities.

Neuroethics is an internationally recognised field that aims to successfully translate brain research in ways that maximise social benefit while minimising harms. The need for Neuroethics has been recognised by all major brain projects around the globe, including the US BRAIN initiative and EU Human Brain Project, and other brain initiatives in Japan, Korea, China, Canada and Australia. The Australian Brain Alliance has made Neuroethics a key priority for the Australian Brain Initiative. The leadership of the Centre in this area has greatly facilitated this development.

Another successful Australian Neuroscience and Society Conference in August 2018. The Brain Function CoE's Neuroethics program was held in Sydney,0in partnership with the International Neuroethics Society, the Monash Institute for Cognitive and Clinical Neurosciences at Monash University, the Centre for Agency Values and Ethics at Macquarie University, and Brain and Mind Centre at the University of Sydney, organised the two-day conference.

"Neuroscience and Society: Ethics, Law, and Technology" was another sold out event with over 100 registrants from government, law, health, academia, and industry. The event included 16 international speakers, and keynote presentations from Roy Baumeister (Florida State University, USA), Michael Valenzuela (University of Sydney), Hannah Maslen (University of Oxford, UK), and Eric Racine (Institut de recherches cliniques de Montreal, Canada).

We featured eight parallel sessions of speakers, covering themes such as:

- Artificial Intelligence, Data, Algorithms
- Neuroscience as Evidence in Legal Proceedings
- Brain Interventions, Identity, and Responsibility
- Dementia and Crime
- Ethical Considerations of Cognitive or Neurological Enhancement
- Brain Interventions, Law, and Regulation
- Selves, Genes, and Technology
- Emerging Technologies and Future Law

The program also hosted a number of additional workshops and symposiums. We were pleased to host Prof Judy Illes (University of British Columbia) in May. Prof Illes is the past president of the International Neuroethics Society and recent awardee of the Order of Canada for her contribution to neuroscience and society. The Centre, in partnership with the Monash Institute of Cognitive and Clinical Neurosciences and Monash Institute of Medical Engineering, held a multidisciplinary workshop on '*The ethics of neurotechnolgocal innovation* 'in Melbourne featuring leaders from bioengineering, law, ethics and philosophy. Prof Illes gave the distinguished lecture to open the event which had over 100 attendees.

The program also held two further symposiums: '*The brain in context'* to look at the way in which society can influence the way in which neuroscience research is conducted and understood; and '*The neuroethics of brain-computer interfaces'*.

Public Engagement

The Neuroethics Program held several highly successful engagement events. *Brave New Brains* was a free public discussion about the future of brain-computer interfaces (BCIs) and the challenges they raise for Australian society. The discussion was held on 27 August at the State Library Victoria and featured leading international and national researchers in neuroengineering, advanced computing, philosophy and ethics.

The event was moderated by the host of Radio National's '*All in the Mind'* program, Lynne Malcolm. An episode of '*All in the Mind'* on BCIs featuring Adrian Carter and two of the event's speakers, Jeffrey Rosenfeld and Hannah Maslen, was recorded after the Brave New Brains event and is now available to download.

We also held two public debates in the lead up to our national conference in Sydney in August: *Do we have a right to psychological privacy* which included Sophie Farthing (Senior Advisor to the Australian Human Rights Commissioner) and Mia Garlick (Director of Policy Australia and New Zealand, Facebook); and *Crime, remorse and punishment* looking at the role of remorse in criminal punishment and the impact of neuroscience on our understanding of remorse.

Monash University also launched *A different lens* video on neuroethics featuring the Neuroethics Program Coordinator, Adrian Carter, discussing the importance of investigating the capabilities of neuroscience and asking the ethical questions that will determine how far we can push the science of mind and behaviour.

Read, listen, watch to discover more about our Neuroethics program

- **Brave New Brains**
- **A different lens**
- **Ethics and the brave new brain**

A different lens

International Engagement

There were key international neuroethics initiatives held in 2018 at which the Centre was able to participate. A/Prof Carter was invited to present at the 2nd Global Neuroethics Summit on the Australian development of a neuroethics framework as part of the Australian Brain Alliance. This framework was published in a special issue of *Neuron*, which also featured articles from the other major brain initiatives around the world. In September, the Organisation for Economic Co-operation and Development (OECD) held a 2-day workshop in Shanghai on responsible innovation of neurotechnology. A/Prof Carter was invited to represent the Australian Government on one of the workshop panels. The meeting featured government officials, small to medium businesses and startups, as well as neuroscientists and ethicists to develop a set of ethical principles to guide the ethical development of technologies impacting on the brain

The Neuroethics Program is currently planning the 2019 meeting, which will be held at Monash University in Melbourne from the 3-4 December.

Dr Hannah Maslen presenting at Brave new Brains

Neuroinformatics

The Centre's neuroinformatics program supports Centre researchers under the guidance of program coordinators Dr Wojtek Goscinski and Dr Pulin Gong.

The neuroinformatics program provides access to high-performance data processing and advanced analysis and visualisation resources; supports the development and publication of software tools and datasets; and builds partnerships with international neuroinformatics infrastructure initiatives.

Analysis and Infrastructure

Australia's specialised high-performance computing facility for imaging and visualisation, MASSIVE, is focused on fast data processing, including processing data in-experiment, large-scale visualisation, and analysis of large-cohort and longitudinal research studies. As a direct result of the partnership between the ARC Centre of Excellence for Integrative Brain Function and MASSIVE, neuroscience has grown to become the largest user community on the MASSIVE high-performance computing facility. As of December 2018, 42 individual neuroscience research projects across Monash University, University of Queensland, University of Sydney, and QIMR Berghofer Medical Research Institute are using the MASSIVE facility for data processing and modelling.

The Centre is the Australian Node (and a Governing Node) of the International Neuroinformatics Coordinating Facility (INCF), an international non-profit organisation devoted to advancing the field of neuroinformatics and global collaborative brain research. The Centre, as the Australian node, coordinated and organised a Neuroinformatics Infrastructure Workshop in August, in Montreal, Canada. This initiative was seeded by discussions at the INCF Council for Science, Technology and Infrastructure, and the Infrastructure Sub Committee, on which Centre Director Gary Egan, Deputy Director Marcello Rosa, and Neuroinformatics Coordinator Wojtek Goscinski are voting members.

Neuroscience research that adheres to the principles of FAIR (Findable, Accessible, Interoperable and Reusable) is dependent on computing infrastructure. The goal of this workshop was to bring together and build an active community of practice of cyber infrastructure and eResearch providers who share an interest in underpinning excellent neuroscience. The workshop attracted 20+ participants from key global infrastructure providers including the INCF; the German data infrastructure resource GIN; the Neuroimaging Informatics Tools and Resources Clearinghouse and the Allen Brain Institute (USA); Canada Open Neuroscience Platform and the Canadian Brain Imaging Research Platform (Canada); Australia's National Imaging Facility, Monash Biomedical Imaging and MASSIVE (Australia).

The workshop identified key common principles across participants, including:

1. A strong commitment to open science and open source, and underpinning reproducible science;
2. The common goal is excellent science, not the infrastructure itself. However, it is now evident that excellent infrastructure is key to excellent science;
3. Sustainability is a challenge and ripe for further discussion and collaboration;
4. Partnership is critical; and
5. Compatibility is critical to underpin ambitious neuroinformatics research projects.

Development of Software Tools

Neural recording data collected from Centre Chief Investigators has been systematically categorised based on different neural levels and recording methods. This data catalogue will be made available by June 2019.

In 2018, the Centre neuroinformatics team coordinated by Dr Pulin Gong organised a list of novel, experimentally testable predictions, arising from their modelling studies about brain dynamics and functions. In order to facilitate collaborations between experimentalists and theoreticians within the Centre, and thus to facilitate cross-theme and cross-scale collaborative research, these testable predictions will be uploaded in 2019 for all Centre personnel to access as appropriate for their research.

Centre researchers continued to refine neural analysis toolboxes developed and made available, initially to Centre researchers and now more widely to the brain research community.

NeuroPatt is a MATLAB toolbox to automatically detect, analyse and visualise spatiotemporal patterns in neural population activity. NeuroPatt can be used to analyse signals recorded by multi-electrode arrays, EEG, MEG, fMRI and other imaging methods such as VSD. Spatiotemporal activity patterns can be detected and analysed by adapting methods from the fields of turbulence fluid and computer vision. This toolbox is available to Centre researchers. https://github.com/BrainDynamicsUSYD/NeuroPattToolbox

SpikeNet provides a computational platform for studying the working mechanisms of cortical microcircuits. SpikeNet supports any synaptic coupling topology, strength and conduction delay defined by users. In addition, it supports a great variety of spiking neuron and synaptic plasticity models. SpikeNet comes with a collection of user-friendly Matlab functions that allow for (1) easy configuration of the spiking network, (2) streamlined post-processing for a wide range of standard analysis results, (3) and visualisation.

NFTsim (Neural Field Theory simulator) is written in C++ and implements streamlined standard methods to solve hyperbolic partial differential equations such as the damped 2D wave equation; time stepping methods to solve ordinary differential equations; and procedures for delay differential equations. Careful numerical analysis has resulted in a suite of methods that is fast, accurate, and robust. The input and output files are both plain-text, so NFTsim can be easily integrated into existing workflows and analyses written in other programming languages. NFTsim comes with a collection of custom made Matlab functions that allow for an easy access to the compiled code, for users without prior knowledge of C++. End-users need only to write plain text files as described in the User Manual. https://github.com/BrainDynamicsUSYD/nftsim

The toolbox is available to all Centre researchers

1

NeuroPatt MATLAB toolbox

2

SpikeNet computational platform

3

NFTsim (Neural Field Theory simulator)

Government and Industry Engagement

The Centre is a member of the Australian Brain Alliance (ABA), a consortium of research institutes, higher education providers, and business leaders in the brain science and technology industry brought together under the auspices of the Australian Academy of Science.

Amongst the ABA's activities is a national campaign that aims to secure support for the Australian Brain Initiative (ABI): A multi-disciplinary, collaborative neuroscience research and translation program that will increase our understanding of the brain and seed Australia's neurotechnology industries for decades to come. Public investment in the ABI will have major economic, social and health implications for Australia. From the development of new high-tech industries based on brain-inspired computing, to targeted treatments for debilitating brain disorders, Australia now has a chance to be at the leading edge of the coming interdisciplinary neuroscience revolution and to help direct it toward matters of concern to Australians.

The investment priorities for the proposed ABI necessarily reflect the broad priorities of the Australian brain research community. The Centre's formation was recognition by the Australian Government of the internationally competitive nature of the Australian neuroscience community. In 2018 a number of Centre Chief and Associate Investigators have had leadership roles in the ABA and represented the Centre's nationally leading research collaboration. The planning is now well advanced for the ABA stated goal to survey the current brain research strengths and capabilities across academia and industry nationally. The work is aimed to lead to the establishment of the ABA priorities for investment and to build Australia's brain research projects and capabilities into truly national endeavour with impact on a global scale.

Equity and Diversity

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

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

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

Following are the major outcomes arising from the GEDC's activities in 2018.

- The committee reviewed GED statistics for speakers at Centre events (and for Centre-speakers at external events), and subsequently updated official GED Key Performance Indicators for the Centre for 2018, 2019 and 2020 with the Australian Research Council. These include the provision of two gender equality and diversity workshops per year and a minimum allocation of respectively three, four and five Primary Caregiver travel grants for 2018, 2019 and 2020.
- The committee updated the Centre's formal GED Policy Guidelines, awarded grants under the Primary Caregiver Travel grant scheme, and developed new accessibility guidelines for all Centre-run activities.
- Unconscious bias training was delivered to all attendees at the Centre's Annual General Meeting in Brisbane in December by professional diversity and inclusion consultants.
- A document outlining the English as a Second Language services available for Centre personnel was developed and made available on the Centre intranet. A focus on support for people for whom English is not their first language was included in the ECR sessions on grant-craft and science communication at the AGM. This focus arose as a consequence of needs identified in the ECR cohort at their annual retreat in August.
- Employee Assistance Programs. A document outlining the services available to Centre personnel at our administering, collaborating and participating organisations has been made available on the intranet.

Centre events

Centre CIs, AIs, PIs, Board members, Administrators, Fellows and Scholars in attendance at the Centre's annual AGM and Science meeting in Brisbane.

CENTRE EVENTS

Brave new Brains, a public event

The major public event on the Centre's calendar for 2018 was 'Brave New Brains', which brought together leading international and national scientists, engineers and philosophers to discuss the future and unique ethical challenges posed by brain-computer interfaces (BCIs).

Host of ABC Radio National's '*All in the Mind*' program, Lynne Malcolm, MC'd the discussion featuring Dr Hannah Maslen (Deputy Director, Oxford Uehiro Centre for Practical Ethics, University of Oxford, UK), Prof Eric Racine (Director, Pragmatic Health Ethics Research Unit, Montreal Institute of Clinical Research, Canada), Prof Jeffrey Rosenfeld (Director, Monash Institute of Medical Engineering, Senior Neurosurgeon, Alfred Hospital), and Dr Isabell Kiral-Kornek (AI and Life Sciences researcher, IBM Research).

Held in Melbourne at the State Library of Victoria, discussion surrounded technological advancements in BCIs and their potential to revolutionise medicine, before opening the floor to a public Q & A session to debate the ethical implications associated with the potential ability to decode and influence brain activity. Key questions included *who should have access to a patient's brain activity?, who is responsible for those thoughts, intentions or actions?, and does this create a new threat to privacy and the freedom of thought?*

The event was a huge success, presented to a sell-out crowd, as well as being made publicly available on YouTube. The topic also formed the basis of a podcast episode of '*All in the Mind*', available on ABC Radio National.

1

YouTube video

Brave New Brains: the future of brain-computer interfaces and the challenges they present

2

Podcast

All in the mind

MAJOR EVENT

Brave New Brains brought together leading international and national scientists, engineers and philosophers to discuss the future and unique ethical challenges posed by brain-computer interfaces (BCIs).

FENS Satellite was the first major meeting run internationally by the Centre for an external audience. The event was well received and a great platform to promote the activities of the Centre

INTERNATIONAL MEETING
FENS Satellite - Receptive Fields: Analysis, Models and Applications

Speakers and attendees at the Centre's International meeting Receptive Fields: Analysis, Models and Applications, held on 6 July 2018 in Berlin, Germany.

The Centre held a satellite meeting in Berlin on 6 July as part of the official 11th FENS Forum of Neuroscience conference. CI Michael Ibbotson (University of Melbourne/ NVRI) and Board Member Ulf Eysel (Ruhr University Bochum) jointly hosted the one-day event featuring eight speakers from around the world with a high impact in the field of visual receptive fields.

Highlighting the impressive vision science research being conducted within Australia, the Brain Function CoE was represented by Liz Zavitz, Trichur Vidyasagar and Michael Ibbotson.

Just as the speaker list represented a wide cross section of the international research community, so did the registration list with researchers attending locally from Germany and nearby European countries, to as far away as Argentina and the US East Coast.

There was an impressive number of Early Career Researchers in attendance enjoying the opportunity to talk science with leaders in the field in an intimate and relaxed setting.

As the first major meeting run internationally by the Centre for an external audience, the event was well received and served as a great platform a great platform to promote the activities of the Centre.

Attendees at the Centre's Mid-Year Science Meeting (Melbourne, June 2018, top) and end-of-year Annual General Meeting and Science Meeting (Brisbane, December 2018, bottom)

CENTRE MEETINGS

Mid-Year Science Meeting

The Centre's mid-year since meeting was held in July in Melbourne. This served as a tremendous opportunity to bring together all Centre Chief Investigators, alongside a number of Centre AIs and Research Fellows to share their current research progress and discuss collaborative opportunities. The meeting yielded some great insights into collaborative research currently being undertaken throughout the Centre, with a particular focus on projects being driven by the ECR cohort. The meeting also provided a platform to plan for Centre research activities through to the end of 2020 and beyond.

AGM and Science Meeting

The Centre's Annual General Meeting (AGM) and Science meeting was held in Brisbane in December, in conjunction with the Australasian Neuroscience Society's (ANS) 38th Annual Meeting. This annual meeting gets better every year and Brisbane was no exception, bringing together over 100 attendees over the course of three days.

The ECRs were the first to gather for their self-organised workshop, which provided an opportunity to improve their grant writing and research proposal skills, along with developing science communication and other career development skills.

The Annual General Meeting followed suit, highlighting the Centre's outreach programs, which incorporated a special 'Unconscious Bias' training session delivered by Dr Jennifer Whelan. This session was well received by all those in attendance, with the key take home message of improving team performance by increasing team diversity.

The Annual Dinner provided both great entertainment and great science, with the Future Leaders Accelerator competition, which entailed ECRs pitching their own independent research ideas. These proposals were then judged by a panel and awarded prizes based on merit, of funds to carry out these projects in 2019.

The Centre's Annual Science Meeting, '*Paint a Great Big Picture*', presented a wide range of high-quality brain research from both Centre members and non-Centre investigators, including a special keynote from International Partner Investigator Keiji Tanaka from the RIKEN Brain Science Institute in Japan.

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

SPONSORED EVENTS

Australasian Cognitive Neuroscience Society

The annual meeting of the Australasian Cognitive Neuroscience Society (ACNS) meeting took place in November at the University of Melbourne, Victoria. Co-organised by A/Prof Katherine Johnson and A/Prof Stefan Bode (University of Melbourne), the event hosted over 340 delegates and included 4 preceding workshops, 5 keynote speakers, 11 student travel awards, 15 student volunteers, 4 symposia, 103 presentations, and 142 posters. The conference exceeded expectations of the attendees, organising committee, and the ACNS executive.

Sponsorship provided by the Centre directly supported travel for international presenter, Professor Nicholas Turk-Browne (Yale University, USA) who gave his Keynote address titled, “Rethinking how memories are stored in the brain” which was well-attended and well-regarded.

CNS*2018 WORKSHOP: Integrative Theories of Cortical Function

As part of the 27th Annual Computational Neuroscience Meeting in Seattle, Centre AI Anthony Burkitt and Fellow Hamish Meffin, co-hosted the workshop, *Integrative Theories of Cortical Function*. The workshop was run as one of five parallel sessions at the Allen Institute, which attracted 70 delegates and encouraged dialogue between theoreticians, experimentalists and modellers.

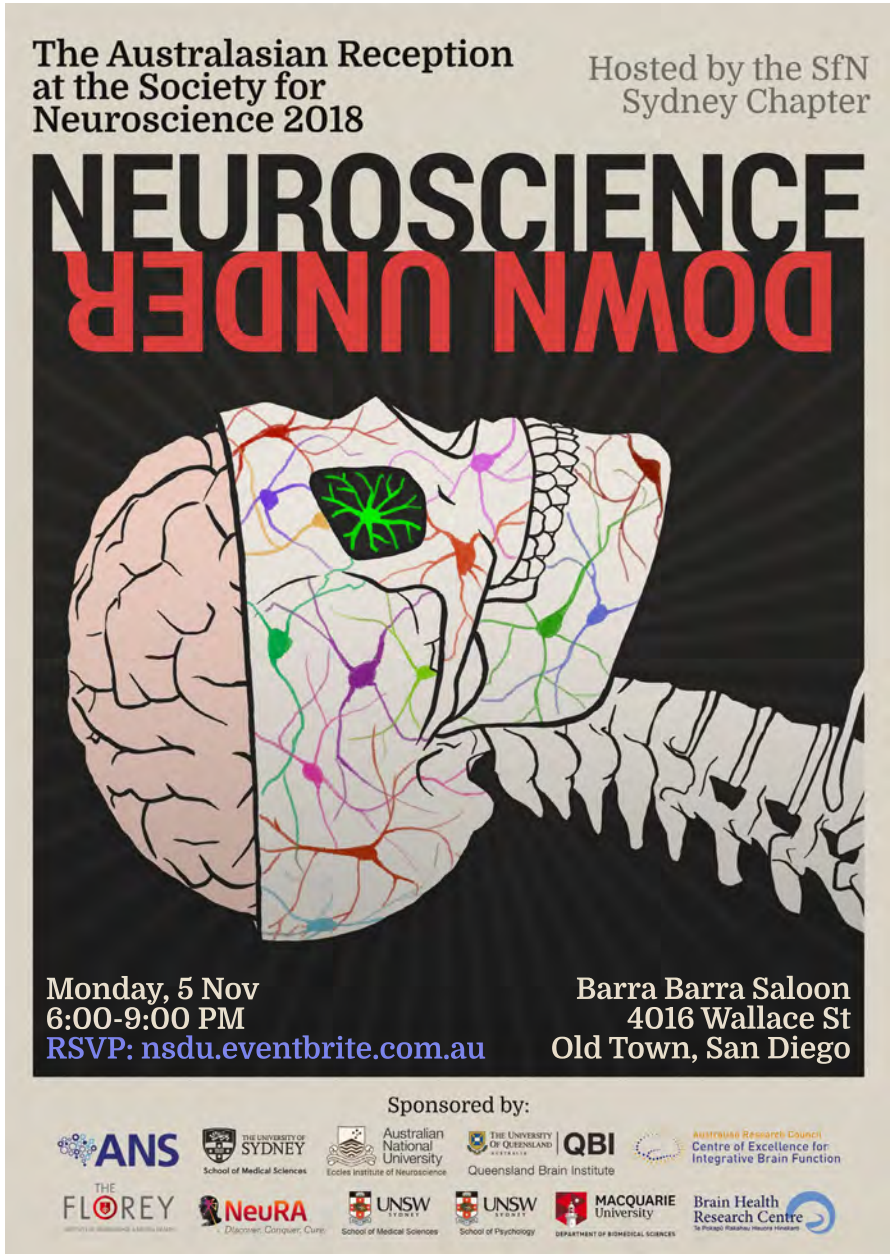
Sponsorship from the Centre contributed towards travel for keynote speakers, including Tatiana Pasternak (University of Rochester, USA).

NEUROENG

The University of Sydney hosted the 11th Australasian Workshop on Neuro-Engineering and Computational Neuroscience at their Camperdown Campus in November 2018. The three-day workshop focused on both research methods and research outcomes.

The event was well attended with some 100 registrants being a great mix of students and academics from all around Australia, as well as three International Speakers; Gus Deco (Universitat Pompeu Fabra, Barcelona), Alain Destexhe (UNIC, Gif-sur-Yvette) and Jianfeng Fen (Fudan University, Shanghai).

Centre funding went towards travel expenses for the international speakers, which helped contribute to the event being such a success.



SPONSORED EVENTS

Neurons, synapses and circuits

Centre CI Pankaj Sah alongside international researchers hosted the three-day conference Neurons, synapses & circuits - from function to disease, at Manly's Q Station, NSW. International plenary talks were given from Richard Huganir (Johns Hopkins University, USA) and Diane Liscombe (Brown University, USA), with a strong representation from Centre speakers too, including CIs Marta Garrido, Ehsan Arabzadeh and Greg Stuart and AI Geoff Goodhill.

The conference was a great success with over 90 attendees made up of students, postdoctoral researchers, laboratory heads and invited speakers. Feedback from attendees was overwhelmingly positive, with several expressing a hope that a similar meeting can be arranged in the not too distant future.

Support from the Centre was used to fund travel and accommodation costs for two international plenary speakers, which meant the calibre of international speakers was high, providing great opportunities for the many early career researchers to interact with influential senior researchers in a relaxed and friendly environment. Several of the international researchers also took time out of their schedules to visit with Centre researchers at their respective nodes.

Neuroscience downunder

Each year as part of the Society for Neuroscience (SFN) annual conference, the Neuroscience Down Under mixer event is held to welcome Australian guests and encourage networking with fellow researchers. As an official satellite event of the main SFN conference, the 2018 event played host to approximately 170 neuroscientists and students from Australia and New Zealand, as well as many expats and overseas colleagues.

Sponsorship from the Centre helped contribute towards catering and venue costs, providing an excellent environment for neuroscientists associated with Australia and New Zealand to meet and discuss collaborations in a relaxed setting. Such an event would not have been possible without support from the Centre of Excellence for Integrative Brain Function.

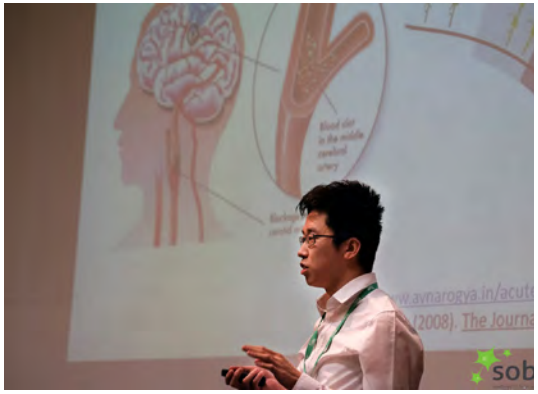
SPONSORED EVENTS

Students of Brain research (SoBR)

In 2018, the SoBR network hosted two major events, both of which were sponsored by the Centre. Their annual professional development dinner (Brains of the Future) was held in June, bringing together postgraduate students, early career researchers, and academics for an enjoyable and informative evening. With keynote presentation by Elly Tanaka (UCSF, USA), the event saw over 130 attendees and included panel discussions and a Q & A session, followed by networking opportunities for students to liaise with each other and academic VIPs.

Later in the year, the SoBR network held their annual symposium, aimed at providing neuroscience and brain research students an opportunity to present their research and network amongst their peers from across institutes and universities in Victoria. Following a plenary session from entrepreneur Michelle Gallaher, the floor was opened for students to present their work and build on their communication skills, with prizes awarded for best presentations.

In both instances, invaluable support from the Centre contributed towards venue and catering costs.



Attendees at SoBR's annual professional development dinner and research symposium.

Key performance indicators

Performance KPIs	Target	Actual	%
Research Outputs – *with Centre acknowledgement or inclusion as an author affiliation*			
Journal articles	40	80	200%
Books	0	2	200%
Book chapters	0	2	200%
Conference papers	3	2	66%
AV recordings	0	9	900%
Patents	0	3	300%
Publication Quality – *with Centre acknowledgement or inclusion as an author affiliation*			
Citations (cumulative)	500	1,251	250%
Average impact factor	4	4.826	120%
Average web views per article	1,000	1,030	103%
Average Altmetric score	10	10.39	104%
Number of training courses offered by Centre			
Professional development training (including media training, pitch training, research translation, journal writing – 2 x online & 2 x face-to-face)	4	6	150%
(All sessions were offered face-to-face, in place of online sessions)			
Number of workshops/conferences held/offered by the Centre			
National science meeting	1	2	200%
International meeting/ workshop	1	1	100%
ECR workshop	1	2	200%
Additional Researchers			
Post-doctoral researchers	25	26	104%
Honours students	8	13	163%
PhD students	25	32	128%
Masters students	0	2	200%
Affiliate Investigators *(students and researchers contributing to Centre activities who do not receive Centre funding)*	70	136	194%
Number of Postgraduate Completions	8	12	150%
Number of Honours Completions	8	11	138%
Number of Mentoring Programs offered by Centre			
Centre induction program	2	2	100%
Formal mentorship program	1	0	0%

Performance KPIs	Target	Actual	%
Number of Presentations/ Briefings to the public, government, industry, business, community, end-user or other professional organisation or body	9	8	89%
Number of new organisations collaborating with, or involved in the Centre	5	20	400%
Number of Gender, Equity and Diversity Workshops			
Face-to Face	1	2	200%
Online *(All sessions were offered face-to-face, in place of online sessions)*	1	0	0%
Number of Travel Grants Given to Primary Caregivers	3	7	233%
End User Impact			
Public lectures/ events	2	3	150%
Primary & secondary education programs	3	5	166%
Brain Dialogue reach (number of web hits)	20,000	39,732	199%
Media – articles	15	34	227%
Media – invited expert commentary	10	8	880%
National/ International Awards	10	21	210%
Accessibility of Research			
Analysis tools available to Centre researchers/ public	1	5	500%
Datasets available to Centre researchers/ public	1	6	600%
Integrative Research			
Number of research outputs with authors from more than one group	20	34	170%
Number of interdisciplinary research programs	8	15	188%
International Profile			
Number of international visitors	10	32	320%
Number of international presentations	25	58	232%
Number of visits to overseas laboratories	16	23	144%

Finance

Statement of income and expenditure

FUNDS CARRIED FORWARD FROM PREVIOUS YEAR	2014	2015	2016	2017	2018	EST. 2019
	$	$	$	$	$	$
Adjustment to carry forward from previous year[1]	-	2,741,132	3,323,469	3,352,518	2,748,592	2,445,345
			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	3,198,884
Australian National University cash contribution	111,324	111,324	111,124	111,324	111,324	111,324
Monash University cash contribution	318,434	318,434	371,625	318,795	318,795	331,546
University of New South Wales cash contribution	-	4,445	148,002	49,334	49,334	49,334
University of Queensland cash contribution	120,390	206,800	120,390	154,370	160,520	160,521
University of Melbourne cash contribution	153,706	155,579	146,444	162,839	154,642	153,707
University of Sydney cash contribution	132,711	241,810	153,706	186,745	153,706	153,707
Human Brain Project (École polytechnique fédérale de Lausanne-EPFL) cash contribution 2	-	25,000	-	-	-	-
International Neuroinformatics Coordinating Facility (INCF) cash contribution	3,142	4,335	22,189	40,399	8,865	4,800
Queensland Institute of Medical Research (QIMR) Berghofer cash contribution	-	-	42,028	31,698	24,343	26,827
Bridge to Mass Challenge	-	-	225,000	25,000	-	-
Other income	4,955	5,700	4,130	16,000	21,139	20,731
TOTAL INCOME AND CARRY FORWARD	**3,788,154**	**6,810,764**	**7,717,223**	**7,554,853**	**7,144,853**	**6,656,726**
EXPENDITURE						
Personnel	657,528	1,892,966	2,585,168	2,822,705	3,152,543	3,400,000
Consultants	21,287	392,266	352,984	414,111	230,976	215,000
Scholarships and support	28,274	115,058	37,517	112,961	136,016	150,000
Purchased Equipment	35,517	132,753	147,279	259,461	39,409	50,000
Lease/ Hired Equipment	4,163	65,607	4,583	15,903	3,437	10,000
Maintenance (IT and lab)	429	78,640	2,889	77,864	14,435	80,000
Research Materials / Experiments	107,769	304,054	172,246	240,924	218,983	250,000
Travel and conferences	102,608	319,067	275,872	345,879	273,676	300,000
Sponsorships - scientific workshops & conferences	4,500	10,429	11,000	20,845	20,891	25,000
Non-research Initiatives	80,217	151,752	259,710	134,553	130,257	125,000
INCF Subscription	-	-	339,905	311,643	332,890	82,182
Other Expenditure	4,730	22,727	175,552	49,412	145,994	150,000
TOTAL EXPENDITURE	**1,047,022**	**3,485,319**	**4,364,705**	**4,806,261**	**4,699,508**	**4,837,182**
BALANCE CARRIED FORWARD TO FUTURE YEARS	**2,741,132**	**3,325,445**	**3,352,518**	**2,748,592**	**2,445,345**	**1,819,544**

In kind contributions

ADMINISTERING AND COLLABORATING ORGANISATIONS	$
Monash University	742,725
The Australian National University	272,542
University of New South Wales	100,000
University of Melbourne	197,856
University of Sydney	332,687
University of Queensland	494,082
TOTAL	**2,139,892**

PARTNER ORGANISATIONS	
Cold Spring Harbor Laboratory	12,500
Duke University	25,000
International School for Advanced Studies	12,500
Karolinska Institute/INCF	94,982
National Institute for Health and Medical Research	12,500
National Institute of Mental Health	12,500
New York University	21,703
QIMR	181,768
Riken Center for Brain Science	12,500
Swiss Federal Institute of Technology/Human Brain Project	-
The Francis Crick Institute (NIMR)	-
Weill Cornell Medical College	17,278
TOTAL	**403,231**
TOTAL	**2,543,123**

1. In 2018, UNSW undertook a reconciliation of the financial activity for the period 2014 to 2017 between them and Neura, their partner in this project. This reconciliation revealed an amount of unexpended funding that had been reported as expenditure in prior years. An adjustment to the 2018 opening balance of $254,354 has been taken up to more accurately reflect the funding available to the Centre.

ADDITIONAL FUNDING

ARC FUNDING

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

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

ARC Discovery Projects:
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 Subwavelengh imaging on a chip
DP170100363
$452,000 (2017-2021)
Centre Investigator: Stan Skafidas

Project Title: Functional Magnetic resonance imaging: Decoding the palimpsest
DP170101778
$370,500 (2017-2020)
Centre Investigator: Peter Robinson

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

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

Project Title: Propagating Neural Waves: Combined Experimental and Modelling Study
DP160104316
$366,939 (2016-2018)
Centre Investigators: Pulin Gong and Paul Martin

Project Title: Neural spike variability: Unifying conflicting views of neural dynamics
DP160104368
$240,000 (2016-2018)
Centre Investigator: Pulin Gong

Project Title: Quantification of whole brain structural connectivity and fibre densities
DP160104193
$345,000 (2016-2018)
Centre Investigator: Steve Petrou

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

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

ARC LIEF Grants:
Project Title: A national magnetic particle imaging facility
LE 190100084
$898,450 (2019)
Centre Investigator: Gary Egan

Project Title: Cryogenic quantum microscope facility
LE180100037
$223,000 (2018)
Centre Investigator: Stan Skafidas

ARC DECRA Awards:
Project Title: Integration of feedforward and feedback circuits for decision-making
DE180100344
$385,551 (2018-2020)
Centre Investigator: Maureen Hagan

Project Title: Neural mechanisms of blindsight: a combined Pphysiological and behavioural study
DE130100493
$375,000 (2013-2018)
Centre Investigator: Leo Lui

OTHER

1	NHMRC Program Grant	$15,000,000
1	NHMRC Infrastructure Grant	$2,750,000
2	NHMRC Development Grants	$1,482,414
3	NHMRC Principal Fellowships	$1,493,280
28	NHMRC Project Grants	$19,706,795
3	Government Grants	$6,828,555
7	International Grants	$6,841,516
6	Industry/Philanthropic Grants	$5,110,000
10	Institutional Grants	$3,251,702

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 interface
BMI	Brain machine interface
BOLD	Blood oxygen level dependent
CI	Chief Investigator
CIBF	Centre for Integrative Brain Function
CoE	Centre of excellence
DCM	Dynamic causal modelling
DECRA	Discovery Early Career Researcher Award
DREADDs	Designer receptors exclusively activated by designer drugs
DTI	Diffusion tensor imaging
ECR	Early career researcher
EEG	Electroencephalography
EPFL	École polytechnique fédérale de Lausanne
FDG	Fluorodeoxyglucose
fMRI	Functional magnetic resonance imaging
GED	Gender, equity and diversity
HBP	Human Brain Project
IL	Infralimbic
INCF	International Neuroinformatics Coordinating Facility
LGN	Lateral geniculate nucleus
MASSIVE	Multi-modal Australian ScienceS Imaging and Visualization Environment
MEG	Magnetoencephalography
mPFC	Medial pre frontal cortex
MRI	Magnetic resonance imaging
MT	Middle temporal visual area
NFT	Neural field theory
PET	Positron emission tomography
PI	Partner Investigator
PL	Prelimbic
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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