THE UNIVERSITY OF MELBOURNE

Department of Optometry and Vision Sciences

RESEARCH PROJECTS 2022

HONOURS, MASTERS, AND PhD

CONTENTS

RESEARCH IN THE DEPARTMENT OF OPTOMETRY AND VISION SCIENCES

The Department of Optometry and Vision Sciences is based in the Faculty of Medicine, Dentistry & Health Sciences (MDHS). Vision science research is multidisciplinary in nature and spans topics from understanding the fundamental workings of the living retina on the microscopic scale to evaluating the viability of crowdsourcing for research. No matter what your major, there are vision research pathways for you. In this brochure we highlight some of the projects available for research students. If you have a passion for vision science that is not covered specifically in this project set, please contact our researchers to discuss further.

For students who have completed an undergraduate degree a research pathway though an Honours or Master of Biomedical Science is an appropriate research path. For students with a BSc (Hons) or BBiomed (Hons) further scientific training through a three to four year PhD or a two year Master of Philosophy would be appropriate.

You can also contact the Departmental Honours and Master of Biomedical Science Coordinator, Prof Trichur Vidyasagar on +61383447004 trv@unimelb.edu.au or the Departmental Graduate Researcher Coordinator for PhD and Master of Philosophy related queries, A/Prof Andrew Anderson on +61390359916 aaj@unimelb.edu.au

FOR FURTHER INFORMATION

HONOURS

http://mdhs-study.unimelb.edu.au/degrees/honours/overview

MASTER OF BIOMEDICAL SCIENCE

https://study.unimelb.edu.au/find/courses/graduate/master-of-biomedical-science/

MASTER OF PHILOSOPHY

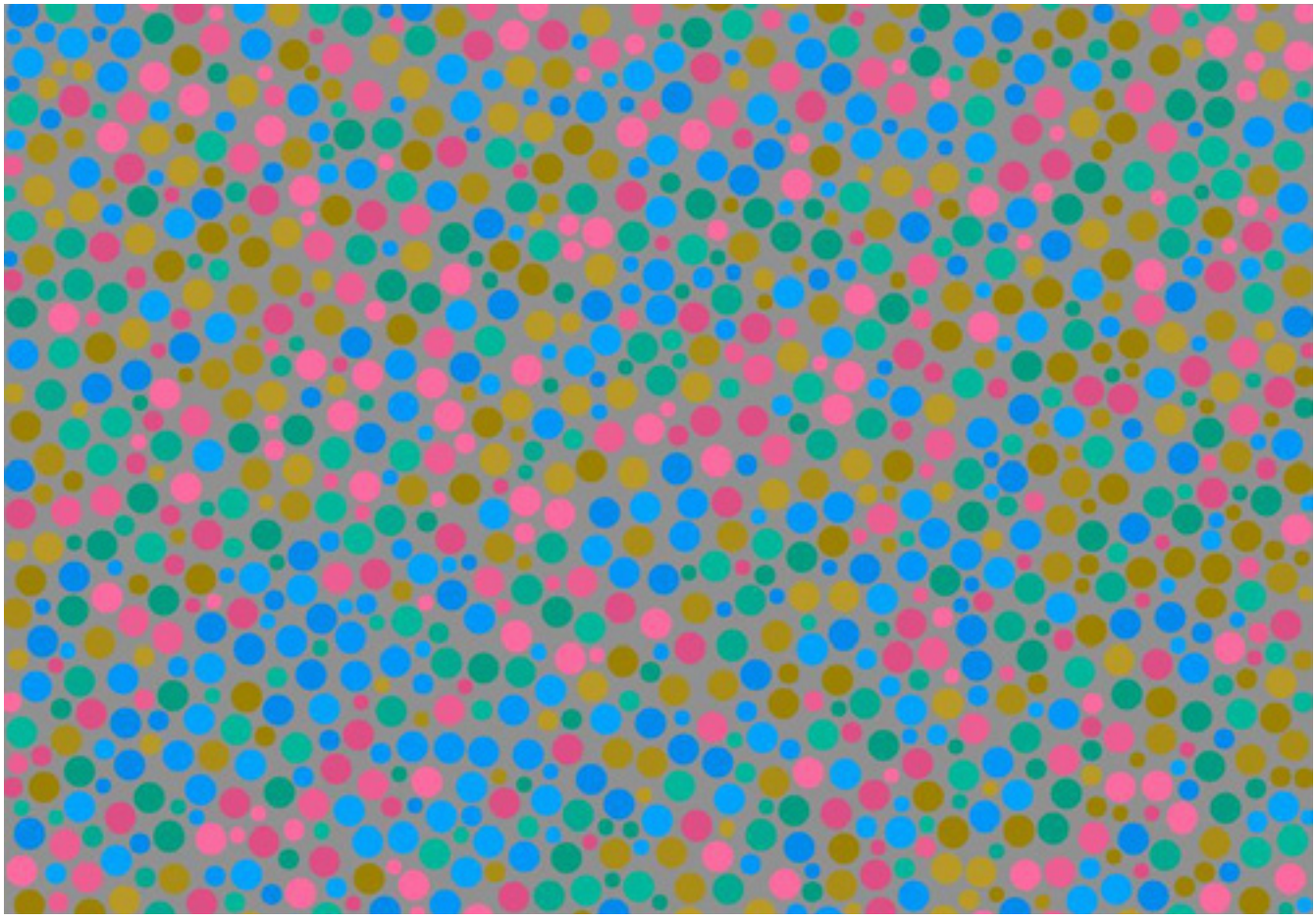
https://study.unimelb.edu.au/find/courses/graduate/master-of-philosophy-mdhs-biomedical-science/

PhD

https://study.unimelb.edu.au/find/courses/graduate/doctor-of-philosophy-medicine-dentistry-and-health-sciences

DEPARTMENT OF OPTOMETRY AND VISION SCIENCES

https://healthsciences.unimelb.edu.au/departments/optometry-and-vision-sciences



ANTERIOR EYE, CLINICAL TRIALS AND RESEARCH TRANSLATION UNIT

LABORATORY HEAD AND PROJECT SUPERVISOR

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PROJECT CO-SUPERVISOR:

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http://healthsciences.unimelb.edu.au/research2/optometry-and-vision-sciences-research/aect-and-rt-unit

Summary of research interests: The *Anterior Eye, Clinical Trials and Research Translation unit* adopts an integrated and innovative approach to research that combines laboratory, clinical and implementation science, as a basis for improving patient outcomes. Our team possess advanced expertise in anterior eye disease (including the development and translation of novel ocular diagnostic devices and therapeutics) and research translation (to develop and test interventions to improve research dissemination and its implementation in practice). Our collaborators include industry, national and international research groups (including researchers in neurology, endocrinology, immunology, neuroscience and chemical engineering), and the Corneal and Ocular Immunology laboratory (led by Dr Chinnery) on projects combining pre-clinical and clinical science.

Anterior eye biomarkers of disease: This program of research investigates using the anterior eye, in particular tears (Figure 1), to provide novel insights into human health. We combine sophisticated clinical techniques with laboratory-based studies to characterise tear film responses in ocular and systemic disease. These investigations are the basis for developing new diagnostic and prognostic tests to inform the management of clinical conditions. Some of our recent studies have identified new tear biomarkers for diabetes, dry eye disease and contact lens discomfort, leading to patents and subsequent projects focussed on the commercialisation of these discoveries.

Figure 1: After non-invasive collection, human tears are analysed using a range of cutting-edge techniques, to quantify parameters such as viscoelasticity, protein composition and lipid content. These studies are the foundation for developing novel lab-on-a-chip tests for ocular and systemic disease.

Research translation: This research focuses on improving patient outcomes by identifying, synthesising and promoting implementation of the best-available evidence in eye care practice.

We are currently undertaking several projects that are developing new clinical tools and digital platforms to support evidence-based practice, in areas such as dry eye disease and age-related macular degeneration. We have developed a free, online platform (in collaboration with A/Prof Michael Pianta) called CrowdCARE, (Crowdsourcing Critical Appraisal of Research Evidence crowdcare.unimelb.edu.au), which uses crowdsourcing to support evidence-based practice. CrowdCARE has the capacity to redefine how clinicians discover and use appraised research evidence, through its capacity to: teach critical appraisal, enable critically appraised research to be shared amongst a global interdisciplinary community, and facilitate contributions and access to an evolving stream of appraised research.

PROJECT 1: QUANTIFYING CORNEAL IMMUNE CELLS IN THE LIVING HUMAN EYE

In vivo confocal microscopy (Figure 2) is a high-resolution imaging technique that permits direct visualisation of corneal nerves and immune cells (dendritic cells) in the living human eye. The cornea is the only tissue in the body that permits this non-invasive, *in vivo* observation of peripheral nerves and immune cells. Corneal dendritic cells are known to be a dynamic cell population, which are known to alter in the density and morphology in response to both ocular and systemic challenge. This project will investigate corneal dendritic cell features, in order to provide insight into these dynamic markers of inflammation.

This project will involve participant recruitment, clinical examinations, and digital image analysis. It is suitable for Honours, Masters and PhD students.

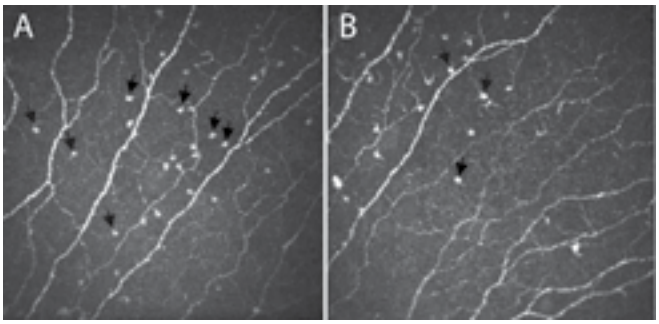

Figure 2: Laser-scanning confocal microscopy images from the central cornea of a person with peripheral neuropathy, at (A) baseline and (B) after eight weeks of oral prednisolone treatment, showing a reduction in the density of putative dendritic cells (white trapezoid-shaped cell bodies).

PROJECT 2: IS CROWDSOURCING A VALID APPROACH TO EVALUATING RESEARCH QUALITY?

Before we 'trust' a research study, we need to consider how it has been performed, and evaluate its potential weaknesses and/or biases. This process, called critical appraisal, enables us to assess the quality of a scientific paper. This is a potentially time-consuming task, which is an established barrier to it being routinely performed. Using data contributed to our online crowdsourced critical appraisal platform (CrowdCARE), the major aim of this project is to evaluate the quality of the data generated using crowdsourcing, with a focus on the appraisal of laboratory-based studies.

This project will engage researchers and students to contribute critical appraisals, and involve considerable data evaluation and statistical analysis. It is suitable for Honours and Masters students.

RECENT RELATED PUBLICATIONS FROM OUR TEAM:

1. McDonnell A, Lee JH, Makrai E, Yeo LY, Downie LE. Tear film extensional viscosity is a novel potential biomarker of dry eye disease. *Ophthalmology* 2019;126(8):1196-8.
2. Downie LE, Wormald R, Evans J, et al. Analysis of a systematic review about blue light-filtering intraocular lenses for retinal protection. *JAMA Ophthalmol* 2019;137(6):694-7.
3. Gad A, Vingrys AJ, Wong CY, Jackson DC, Downie LE. Tear film inflammatory cytokine upregulation in contact lens discomfort. *Ocul Surf* 2019;17(1):89-97.
4. Pianta MJ, Makrai E, Verspoor KM, Cohn TA, Downie LE. Crowdsourcing critical appraisal of research evidence (CrowdCARE) was found to be a valid approach to assessing clinical research quality. *J Clin Epidemiol* 2018;104:8-14.
5. Downie LE, Gad A, Wong CY, et al. Modulating contact lens discomfort with anti-inflammatory approaches: a randomized controlled trial. *Invest Ophthalmol Vis Sci* 2018;59(8):3755-66

CLINICAL PSYCHOPHYSICS UNIT

LABORATORY HEAD

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PROJECT CO-SUPERVISOR

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Lab blog: http://uomcpulab.wordpress.com/

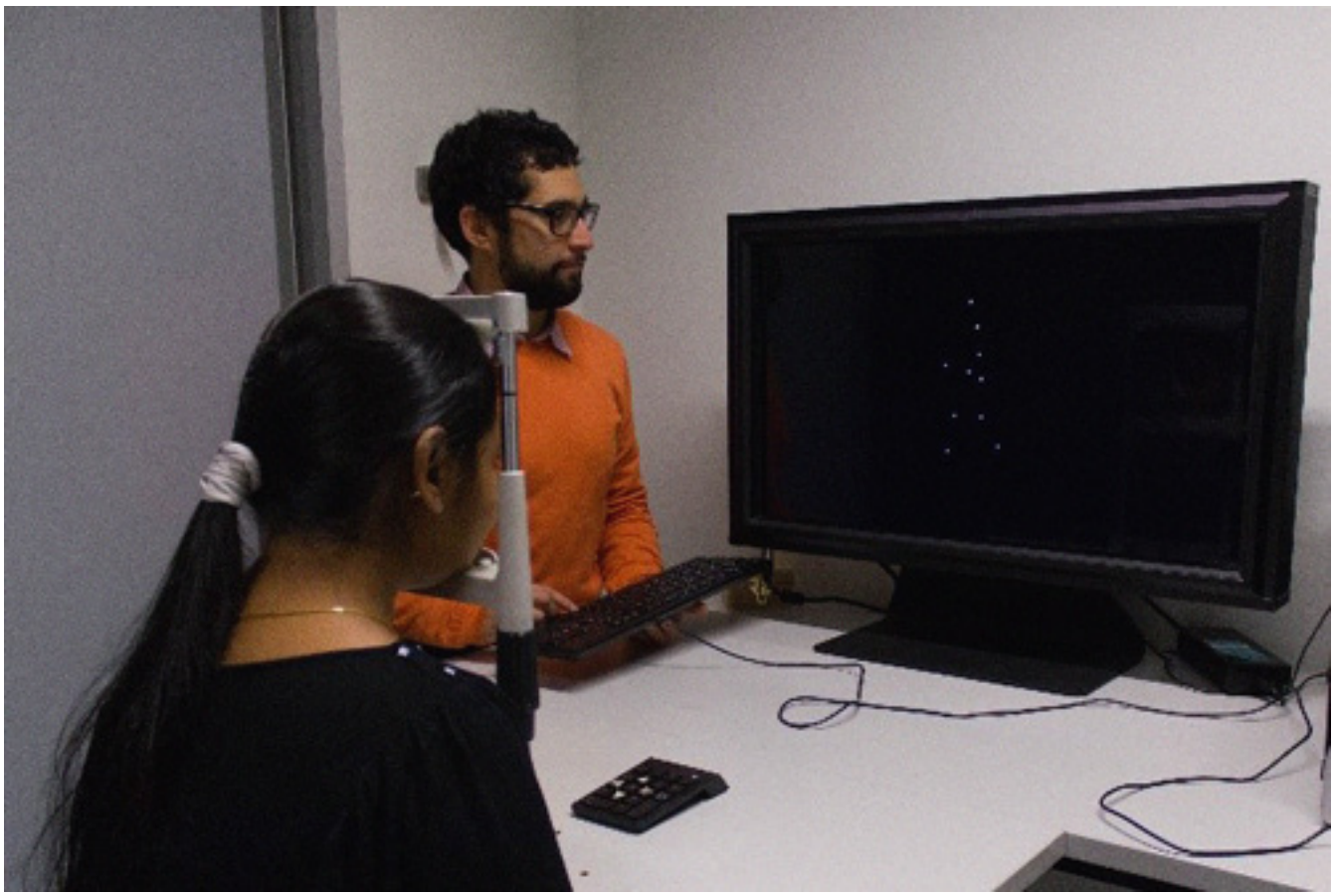
Summary of lab interests: Our research aims to better understand normal visual processing and damage due to disease. We have specific interests in the study of glaucoma, migraine, and the process of normal ageing. Our applied aims include developing better clinical tests for the assessment of vision loss; determining methods of preventing visual damage, and improving understanding of the consequences of vision loss on performance in natural visual environments and day-to-day tasks. Our current studies use a variety of methods including visual psychophysics (testing visual performance), human electrophysiology and brain and ocular imaging. Our work is highly collaborative with colleagues from ophthalmology, psychology, physiotherapy, neurology and neuroimaging.

RESEARCH DOMAIN 1: UNDERSTANDING MOTION PERCEPTION IN PERIPHERAL VISION

Peripheral vision is very sensitive to visual motion cues. These cues are used to identify objects in our periphery and to segment them from other background features. This project will explore which stimulus features are important to the ability to segment moving objects in our peripheral vision, as well as studying whether individual differences in simple aspects of motion perception predict individual ability to identify moving objects on noisy backgrounds.

PROJECT 2: UNDERSTANDING ANATOMICAL LINKS BETWEEN RETINAL STRUCTURE AND RETINAL VASCULATURE: INTER-INDIVIDUAL DIFFERENCES

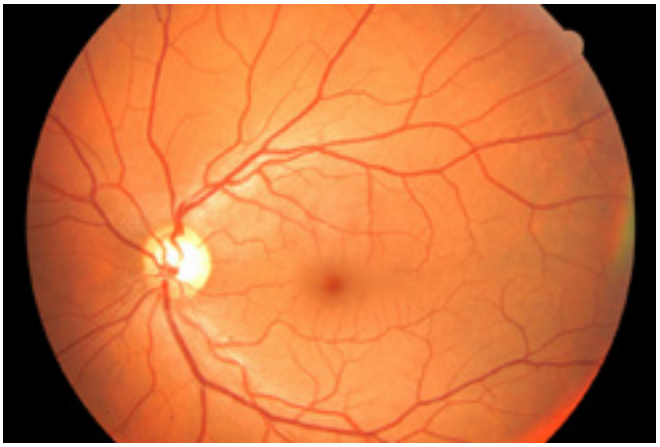
Recent developments in ophthalmic imaging have allowed ready, unprecedented, ability to observe microstructure in the human retina. One such technique is OCT-angiography, which enables indirect visualisation of retinal vessels. It is increasing recognised that there are broad inter-individual differences in retinal vasular trees. This project will examine whether the physical shape of the fovea influences the shape of the retinal vasculature. Understanding this relationship in those with normal vision is important for a diversity of future clinical applications of this tool, and may also be important for future developmental studies.



PhD student, Juan Sepulveda, measuring motion cues used to identify human movement.

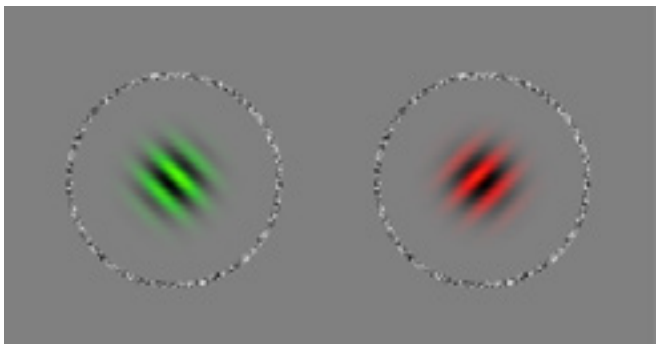
RESEARCH DOMAIN 3: WHAT EXTERNAL FACTORS INFLUENCE VISUAL PLASTICITY?

We have recently been studying whether short-term plasticity in the visual system is influenced by factors such as age, or interventions such as exercise. An additional intervention of interest to us is caffeine. Caffeine is a widely used psychostimulant that is associated with increased acetylcholine in the brain. Acetylcholine is a neuromodulator that plays an important role in the processing of visual information. In particular, acetylcholine and the cholinergic system are thought to be involved in adult brain plasticity, which can be measured by temporary patching of one eye for a few hours. A recent study showed that perceptual eye dominance plasticity is reduced with pharmacological administration of donepezil (an acetylcholine enzyme inhibitor) in healthy human observers. Here, we test whether temporarily manipulating caffeine levels has a similar effect on perceptual eye dominance plasticity.



RECENT RELATED PUBLICATIONS FROM OUR TEAM:

- Chan YM, Pitchaimuthu K, Wu Q-Z, et al. Relating excitatory and inhibitory neurochemicals to visual perception: A magnetic resonance study of occipital cortex between migraine events. *PLoS One* 2019;1-13.
- Nguyen BN, Hew SA, Ly J, et al. Acute caffeine ingestion affects surround suppression of perceived contrast. *J Psychopharmacol* 2018;32:81-88.
- Sepulveda JA, Anderson AJ, Wood JM, McKendrick AM. Differential aging effects in motion perception tasks for central and peripheral vision. J Vis. 2020;20(5):8.
- Sepulveda JA, Turpin A, McKendrick AM. Individual differences in foveal shape: feasibility of individual maps between structure and function within the macular region. *Invest Ophthalmol Vis Sci*, 2016: 57: 4772-4778.



Binocular rivalry stimuli, commonly used to infer visual system plasticity. The red and green stimuli are presented to each eye separately, with the combined percept swapping regularly from one to the other (rivalrous percept).

CLINICAL VISION RESEARCH AT THE AUSTRALIAN COLLEGE OF OPTOMETRY

PROJECT SUPERVISOR

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Twitter: @MPOrthoptics

Summary of research interests: This strand of research based at the National Vision Research Institute is focused around undertaking clinically oriented vision research, including public eye health, aimed at improving the health and well-being of the community. The Australian College of Optometry sees over 60,000 Victorians annually across the region who live with socioeconomic disadvantage, which in turn is a risk factor for health inequalities. Projects are centred around providing an evidence base to support the care of these groups, including children and families, older adults, people living with disability and those residing in aged care facilities.

FOCUS AREA 1: BINOCULAR VISION

Binocular vision helps us in many ways that we take for granted. Problems with depth perception can affect our ability to judge distances, complete precise hand-eye tasks and move around confidently. If our eyes are not coordinated, this can lead to symptoms of eye strain or distressing double vision, increasing risk of falls and affecting day to day tasks. This research program focuses on the clinical measurement of depth perception and binocular vision, in people of all ages, with and without other long term conditions.

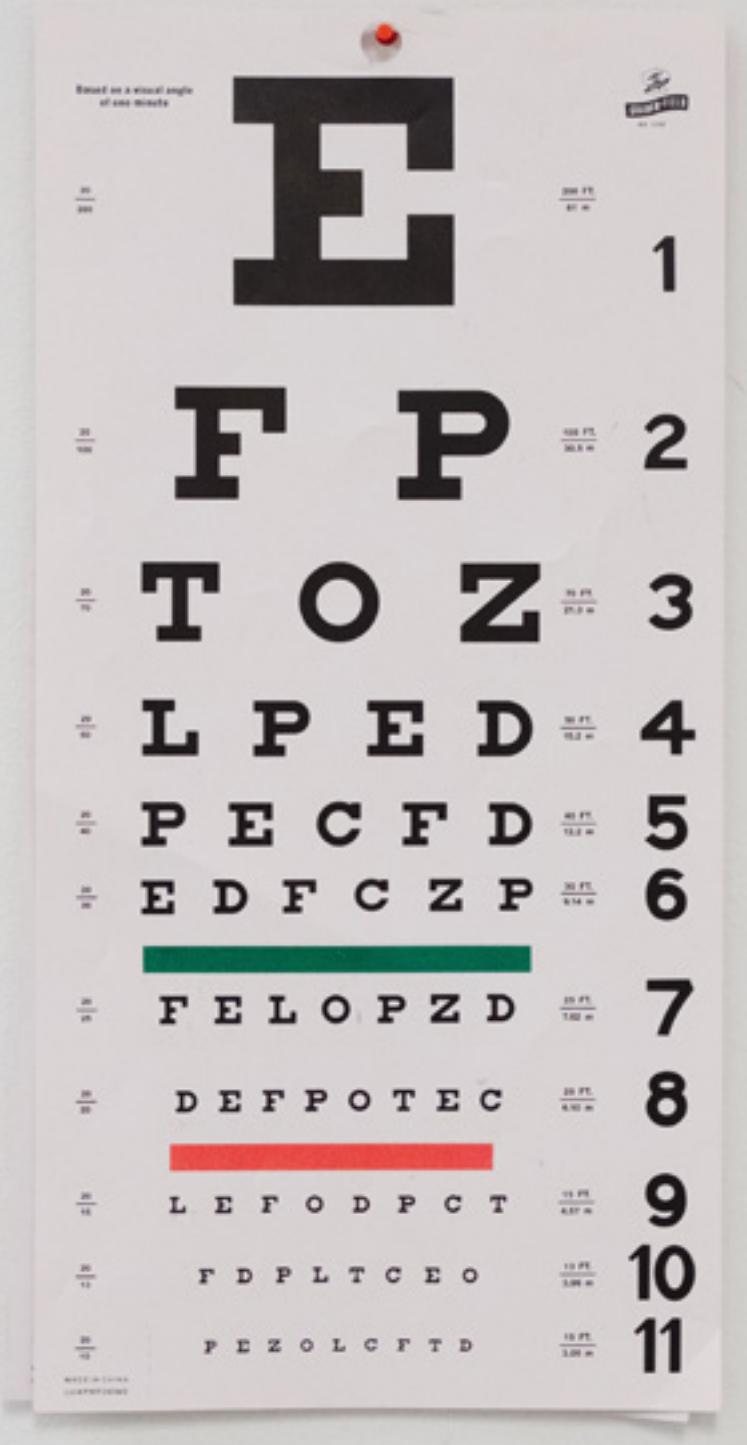
FOCUS AREA 2: AMBLYOPIA

Amblyopia, or 'lazy eye', is the most common cause of treatable sight loss in young children, occurring in approximately 2% of Australians growing up. Untreated amblyopia has been associated with poor reading scores, fine motor coordination difficulties and low self-esteem in children and young people. Early diagnosis and treatment results in better visual outcomes, but problems with visual processing and depth perception can remain, even after successful treatment. Many aspects of how children respond to amblyopia treatment are still poorly understood. This program of mixed methods research focuses on the clinical diagnosis and treatment of amblyopia in children, to generate more evidence on barriers to successful amblyopia treatment and design adaptive treatment protocols to maximise visual function in amblyopia.

FOCUS AREA 3: LOOKING AFTER OLDER EYES

Older adults are at greater risk of developing eye conditions that threaten sight, yet only half of older adults in Australia attend for regular sight tests. Poor vision in older adults is a significant risk factor for falls, and through impact on ability to engage in daily activities and socialising, is associated with increased risk of depression and cognitive decline. Maximising eyesight for older adults with other co-morbidities such as diabetes, dementia or cardiovascular disease is therefore an important step in maintaining quality of life and independence, thus the optometrist can make an important contribution to integrated care for these conditions that is yet to be fully recognised. This program focuses on the role of routine eye examinations for older adults living with long term conditions.

Data collection at Insomnia Gaming Festival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CORNEAL AND OCULAR IMMUNOLOGY

LABORATORY HEAD

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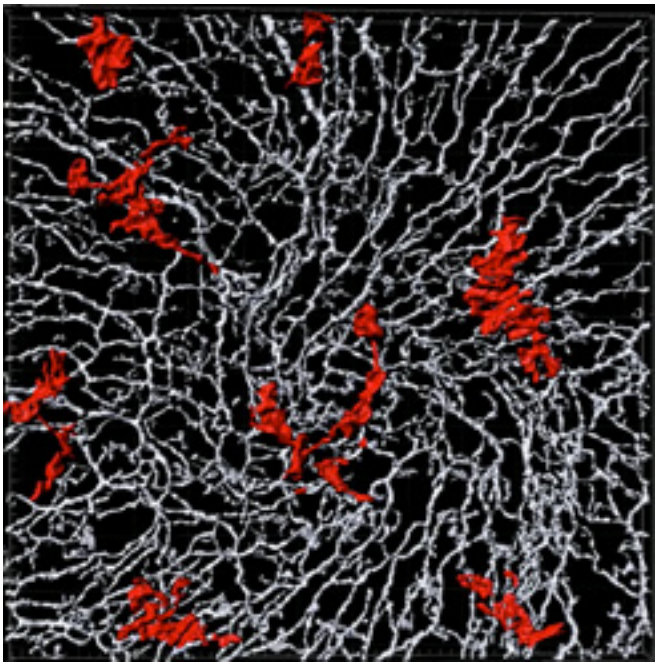
https://healthsciences.unimelb.edu.au/research-groups/optometry-and-vision-sciences-research/corneal-and-ocular-immunology-unit

Summary of lab interests: We investigate the structural, physiological and immunological interplay between immune cells and other non-immunological structures such as sensory nerves and epithelial cells in the cornea during homeostasis and disease. Techniques used in our lab include in vivo clinical imaging of the cornea, ex vivo confocal microscopy and 3D image reconstruction and molecular biology and protein assays. We also collaborate closely with Dr Laura Downie, who leads the Anterior Eye, Clinical Trials and Research Translation Unit in DOVS.

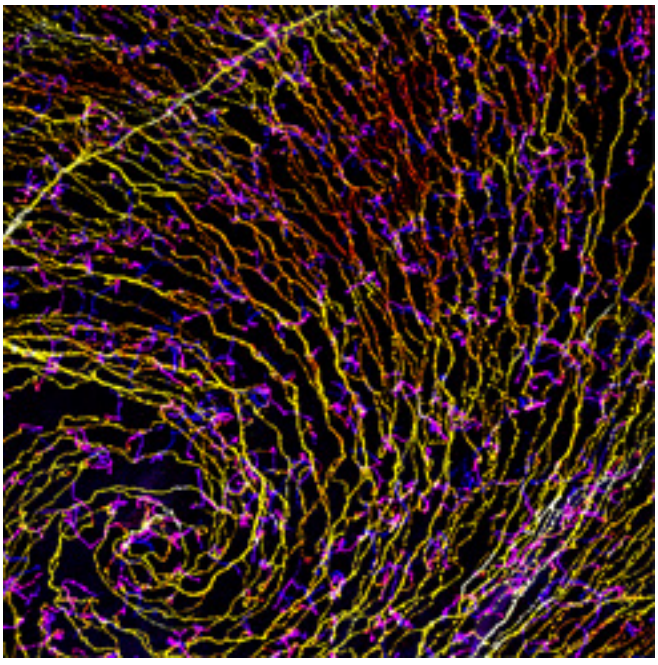
PROJECT 1: TIME COURSE OF SENSORY NERVE RECOVERY AFTER EPITHELIAL INJURY

Following corneal epithelial injury, the regeneration of the corneal nerves is a slow process, often taking months to recover. However, despite this slow recovery process,

the cornea appears structurally normal, with the epithelial cells and tissue architecture appearing clear and healthy. We propose that this is due to differential rates of recovery of different nerve plexi. This project will quantify the regeneration rates of nerves and measure neuropeptide secretion in distinct regions of the cornea after injury. Techniques include animal handling, clinical imaging, confocal microscopy, protein assays, 3D image reconstruction and image analysis. This project would be suitable for Honours, Masters or PhD student.



Corneal macrophages living just beneath the corneal epithelial nerve plexus.



Corneal nerves forming a whorl pattern in the central epithelium

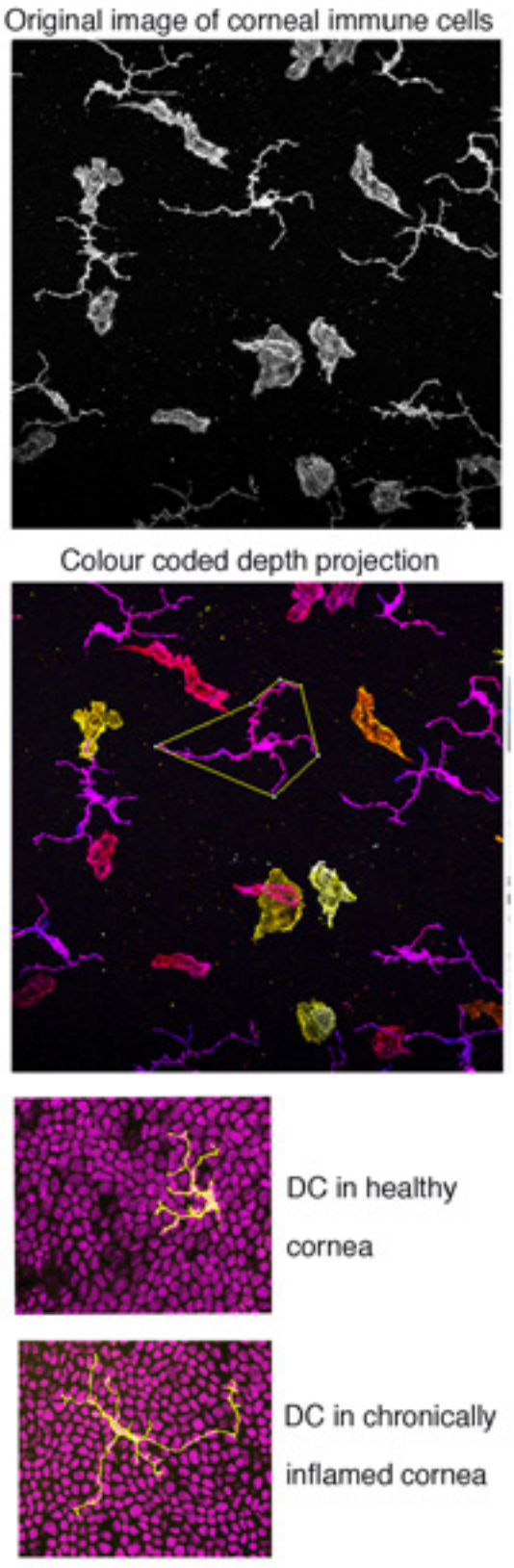
PROJECT 2: CORRELATING IMMUNE CELL MORPHOMETRY WITH MARKERS OF CELLULAR ACTIVATION IN THE MOUSE CORNEA.

Recent clinical studies have demonstrated using in vivo confocal microscopy that corneal immune cells change their shape and size in response to local and systemic inflammatory diseases. It is unclear how the changes in cell shape and size relate to function and maturation. In this project, mouse models of corneal inflammation will *Resident immune cells (dendritic cells and macrophages) in mouse cornea. Shape and size analysis reflect functional alterations in immune cells* be used to correlate morphological changes in immune cell populations with alterations in cell surface markers indicative of cell activation. These findings will provide clinically translatable information that will shed light on the functional relevance of morphological changes to immune cells in the human cornea. This project will involve animal handling, clinical imaging, ex vivo confocal microscopy, flow cytometry and 3D image reconstruction and image analysis.

This project would be suitable for Honours, Masters or PhD students.

RECENT RELATED PUBLICATIONS FROM OUR TEAM:

1. Chinnery HR, Zhang XY, Wu CY, Downie LE. Corneal immune cell morphometry as an indicator of local and systemic pathology: A review. Clin Exp Ophthalmol. 2021 Jul 9. doi: 10.1111/ceo.13972. Epub ahead of print. PMID: 34240800.
2. Jiao, H., L. E. Downie, X. Huang, M. Wu, S. Oberrauch, R. J. Keenan, L. H. Jacobson and H. R. Chinnery. 2020. "Novel alterations in corneal neuroimmune phenotypes in mice with central nervous system tauopathy." *J Neuroinflammation* 17(1): 136.
3. Wu, M., L. E. Downie, L. M. Grover, R. J. A. Moakes, S. Rauz, A. Logan, H. Jiao, L. J. Hill and H. R. Chinnery. 2020. "The neuroregenerative effects of topical decorin on the injured mouse cornea." J Neuroinflammation 17(1): 142.
4. Jiao H, Naranjo Golborne C, Dando S, McMenamin PG, Downie LE & Chinnery HR. 2019. Topographical and morphological differences of corneal dendritic cells during steady state and inflammation. Accepted for publication in *Ocular Immunology and Inflammation*
5. Downie LE, Naranjo Golborne C, Chen M…Chinnery HR et al. Recovery of the sub-basal nerve plexus and superficial nerve terminals after corneal epithelial injury in mice. *Exp Eye Res* 2018; 171: 92-100.



Resident immune cells (dendritic cells and macrophages) in mouse cornea. Shape and size analysis reflect functional alterations in immune cells

OCULAR BIOMARKER LABORATORY

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https://healthsciences.unimelb.edu.au/research-groups/optometry-and-vision-sciences-research/ocular-biomarker-laboratory

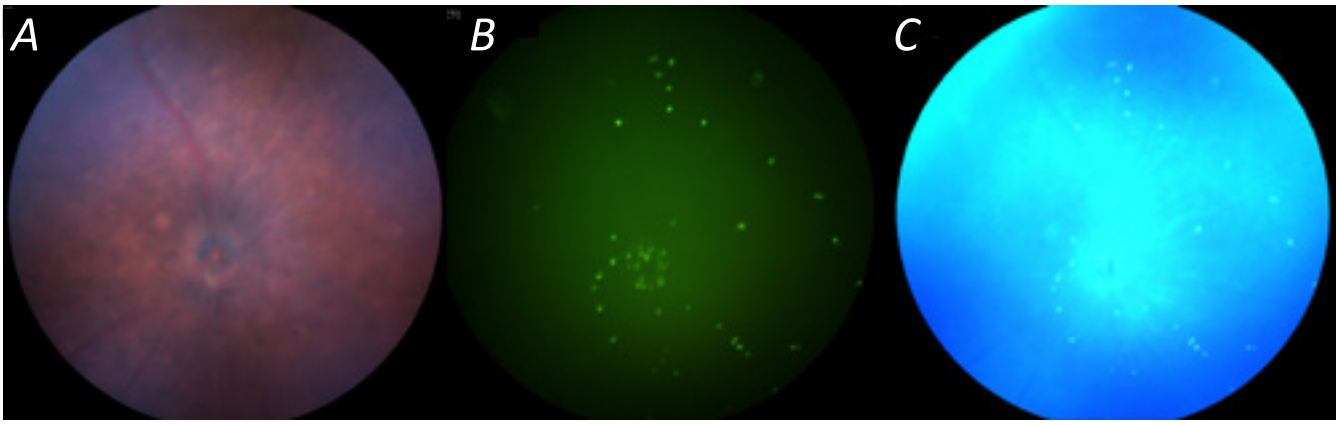
Summary of lab interests: The eye affords a unique opportunity to gain insights into what is occurring in the brain. It is the only place in the body where neurons and blood vessels can be directly visualised. Moreover, neurological diseases such as Alzheimer's disease, Parkinson's disease and multiple sclerosis have been shown to exhibit changes in the eye which can be measured with currently available clinical tools and emerging technologies.

PROJECT 1: IMAGING PARKINSON'S DISEASE IN THE EYE

Diagnosis of Parkinson's disease is a difficult and lengthy process. A hallmark of Parkinson's is alpha-synuclein deposits in the brain but the skull makes these difficult to detect. Interestingly, in our lab and others, alpha-synuclein has been identified in the retina, an outpouching of the central-nervous-system. The aim of this project is to provide proof-of-principle that it is possible to image alpha-synuclein in the mouse retina. Given the clear optics the eye, we will fluorescently tag an antibody and directly image them in living animals. The capacity to develop early, specific biomarkers for PD is pivotal for development of treatments.

PROJECT 2: AN EYE ON ALZHEIMER'S AND PARKINSON'S DISEASE: CHARACTERISING TAU PROTEIN CHANGES IN THE RETINA

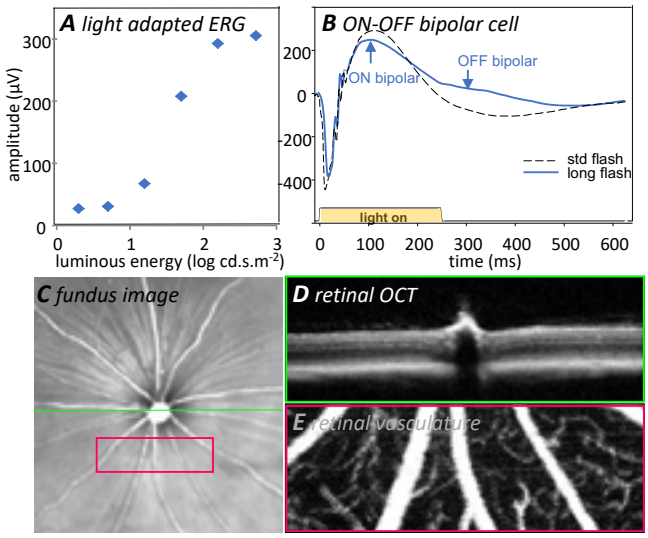
Alzheimer's and Parkinson's disease exhibit neurofibrillary tangles consisting of abnormal tau proteins. These proteins are also found in the eye and our group has shown the absence of them can modify retinal measures that can also easily be conducted in patients. The current project will build on this work and characterise retinal imaging changes in a mouse model of abnormal tau aggregation. In this manner, the project will form the building blocks for testing whether common clinical retinal assessments (i.e. optical coherence tomography, hyperspectral imaging, electroretinography) may be useful for early detection of Alzheimer's and Parkinson's disease.



Alpha-synuclein imaging in the eye A retinal photograph B following injection of a fluorescently labelled tag, alpha-synuclein (green spots) can be visualised C. A combination image where some retinal detail and tagged alpha-synuclein can be simultaneously visualised.

PROJECT 3: PARKINSON'S DISEASE: USING A RETINAL STRESS TEST TO UNCOVER EARLY METABOLIC CHANGES

One of the earliest pathological changes in Parkinson's disease are changes to metabolism. Retinal photoreceptors are the most highly metabolic tissue per weight in the body and hence they form a logical location to examine early Parkinson's changes. By challenging the retina with light (akin to a photographic flash) retinal metabolism can be probed in mice with or without Parkinson's at various disease stages. This will shed light on whether retinal metabolic changes may be an early marker of Parkinson's disease and improve our undertsanding of it's pathogenesis. The capacity to develop early, specific biomarkers for Parkinson's disease is pivotal for development of treatments.



Functional and structural assessment of retinal health in animals models of neurodegenerative disease

PROJECT 4: EXAMINING NEUROINFLAMMATION IN A MODEL OF PARKINSON'S DISEASE

Neuroinflammation is central to the pathophysiology of Parkinson's disease, however it is challenging to measure in vivo. Assessment in peripheral systems (such as blood) may be indicative but are limited due to the distinct inflammatory pathways found within the central nervous system. It is established from Parkinson's disease human post-mortem substantia nigra tissue, that microglia become activated and release specific proinflammatory cytokines that lead to neurodegeneration. The eye is an out-pouching of the brain and literature indicates that 3 dimensional scans of the retina show thickening which is typical of active inflammation. What has not been examined are inflammatory markers which correspond to these changes. This project aims to examine this link in a mouse model of Parkinson's disease.

RECENT RELATED PUBLICATIONS FROM OUR TEAM:

1. Nguyen CT, Hui F, Charng J, Velaedan S, Van Koeverden A, Lim JK, He Z, Wong VHY, Vingrys AJ, Bui BV, Ivarsson M (2017). Retinal biomarkers provide "insight" into cortical pharmacology and disease. *Pharmacology and Therapeutics*. 175: 151-177.
2. Lim JK, Li QX, He Z, Vingrys, AJ, Wong, VHY, Currier N. Mullen J, Bui BV, Nguyen, CT (2016). The Eye as a Biomarker for Alzheimer's Disease. *Front Neurosci* 10, 536.
3. Habiba U, Merlin S, Lim JKH, Wong VHY, Nguyen CT, Morley JW, Bui BV, Tayebi M. Age-Specific Retinal and Cerebral Immunodetection of Amyloid-beta Plaques and Oligomers in a Rodent Model of Alzheimer's Disease. *J Alzheimers Dis* 2020.
4. Shahandeh A, Bui BV, Finkelstein DI, Nguyen CT. Therapeutic applications of chelating drugs in iron metabolic disorders of the brain and retina. *J Neurosci Res* 2020.

OCULAR PHYSIOLOGY LABORATORY

LABORATORY HEAD

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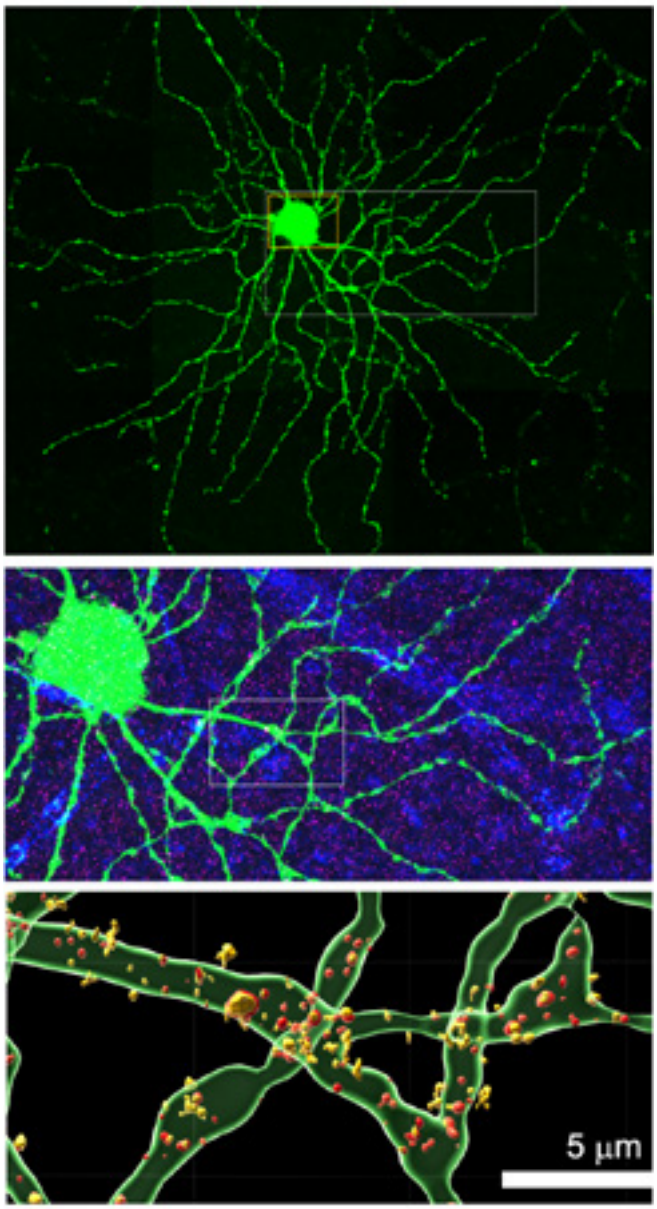
https://healthsciences.unimelb.edu.au/research-groups/optometry-and-vision-sciences-research/ocular-physiology-lboratory

Summary of lab interests: Our laboratory is interested in understanding the causes of retinal and optic nerve injury in diabetes and glaucoma. We are also interested in developing new ways to clinically detect eyes at risk of vision loss from these conditions.

PROJECT 1: UNDERSTANDING HOW PRESSURE AFFECTS GANGLION CELLS IN GLAUCOMA

Our investigations of glaucoma hope to shed light on how the cells that connect the eye to the brain, the retinal ganglion cells, are able to adapt to changes in their local environment. When such adaptation mechanisms fail ganglion cells undergo programmed cell death. Ganglion cells have to cope with constant changes in the pressures in and around the eye; intraocular pressure, blood pressure and intracranial pressure. As the eye gets older the capacity to cope with stress is diminished, but at the moment we don't fully understand why this occurs. In order to study how ageing and other risk factors impact the capacity for retinal ganglion cells to cope with stress we have developed both acute and chronic model of intraocular pressure elevation. We will study ganglion cell responses to stress by relating their function (using electroretinography), structure (using imaging) and dendritic morphology to a range of cellular processes that might help ganglion cells to work better (e.g. communication synapses, autophagy for self-repair, energy supply).



The figure shows a ganglion cell in a mouse eye, that we can co-stain for synapses to better understand why ganglion cells are affected by high eye pressure.

PROJECT 2: STUDIES OF RETINAL VASCULAR AUTOREGULATION

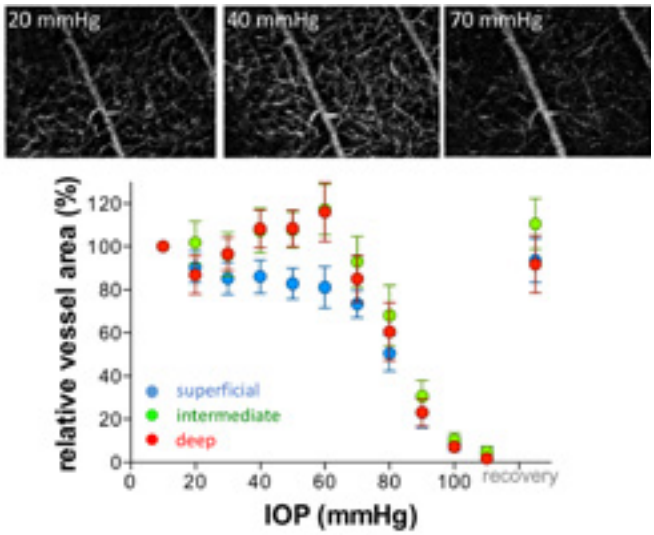
The retina and brain are the most highly energy demanding tissues in the body. In the retina, the need for optical clarity and many neurons for good vision comes at the expense of fewer blood vessels. In addition to this the retina lack of ways to store energy. As such the retina is completely dependent on a stable blood supply to deliver oxygen and glucose. In the retina there are three major vascular beds (superficial, intermediate and deep) that respond to local changes in blood and eye pressure as well as times when energy usage is high. This local control system Using optical coherence tomography angiography, it is possible to show that as eye pressure increases the blood vessels in the superficial layer (blue) is more compromised *than those in the intermediate (green) and deeper layers (red). We will undertake further studies to understand the molecular pathways that mediate retinal autoregulation and how they are altered in diseases such as diabetes and glaucoma.* Is known as vascular autoregulation and involves cells lining the blood vessel walls (endothelial cells) as well as neurons and supporting glial cells (astrocytes and microglia). The failure of autoregulation has been implicated in retinal disease such as diabetes and glaucoma. In these studies, we will employ optical coherence tomography imaging to assess autoregulation in animal models of retinal disease.

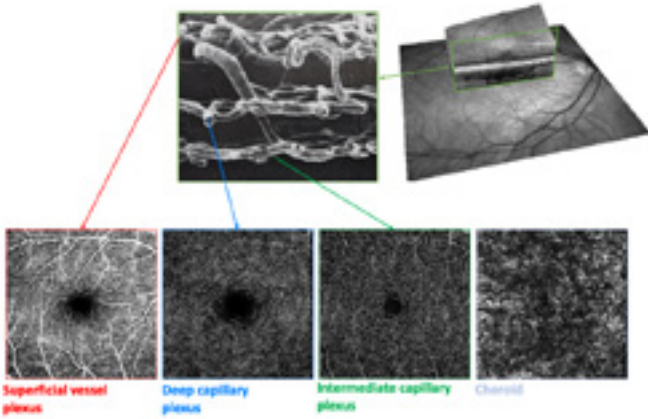
PROJECT 3: DEVELOPING A CLINICAL TEST OF VASCULAR AUTOREGULATION

As we better understand how blood vessels in the eye work to supply blood when needed, we use this information to help us develop better clinical tests for detecting blood vessels that don't work as they should. Optical coherence tomography angiography can be used in the laboratory as well as in the clinic. By using a flickering light stimulus we challenge the blood vessels to dilate, in order to get more blood to support the increased communication between retinal neurons that occurs with lights repeatedly turning on and off. Using this approach we may be able to identify eyes that have regions of blood vessels that do not respond as they should. We believe that this will help us detect earlier those eyes that might go on to develop vision loss.

RECENT RELATED PUBLICATIONS FROM OUR TEAM:

- Grant ZL, Whitehead L, Wong VHY, He Z, Yan RY, Miles AR, Benest AV, Bates DO, Prahst C, Bentley K, Bui BV, Symons RC, Coultas L. Blocking endothelial apoptosis revascularises the retina in a model of ischemic retinopathy. J Clin Invest. 2020:127668.
- Zhao D, He Z, Wang L, Fortune B, Lim JKH, Wong VHY, Nguyen CTO, Bui BV. Response of the Trilaminar Retinal Vessel Network to Intraocular Pressure Elevation in Rat Eyes. Invest Ophthalmol Vis Sci. 2020 ;61(2):2.
- Liu G, Li H, Cull G, Wilsey L, Yang H, Reemmer J, Shen HY, Wang F, Fortune B, Bui BV, Wang L. Downregulation of Retinal Connexin 43 in GFAP-Expressing Cells Modifies Vasoreactivity Induced by Perfusion Ocular Pressure Changes. Invest Ophthalmol Vis Sci. 2021;62:26. doi: 10.1167/iovs.62.1.26.





Optical coherence tomography angiography can help us to discern key blood vessel layers in the retina

OPTOLOGICAL LABORATORY

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https://healthsciences.unimelb.edu.au/research-groups/optometry-and-vision-sciences-research/optological-laboratory

The Optological Laboratory non-invasively investigates how the human eye and brain function, both in normal observers and those with eye disease. Although our understanding of neuroscience has been greatly enhanced through electrophysiological recordings from individual neurons and through computer imaging of gross neural activity across the brain, such information only tells us part of how the brain and eye work. Ultimately, we also need to understand how the eye and brain behave in response to various forms of information, and to ascertain what functional limits exist in processing such information. By combining results from a range of studies – including electrophysiological, imaging and behavioural studies – a more complete understanding of neuroscience be achieved.

Our laboratory uses a range of techniques to determine how the eye and brain behave, many of which can be classed under the general heading of psychophysical methods. Sometimes our investigations involve visual targets used in clinical tests of vision, allowing us to better understand how such tests work and allowing more effective clinical tests to be developed. Other investigations use customised visual stimuli and special experimental protocols to examine how the eye transmits information to the brain, and also how the brain processes this information in order to make decisions. The laboratory is well equipped to undertake a wide range of behavioural experiments and so can address a broad range of behavioural questions, both in the clinical and basic sciences.

PROJECT 1: EXAMINING A NOVEL, COMPUTERISED TEST OF COLOUR VISION FOR DETECTING & MONITORING DISEASE

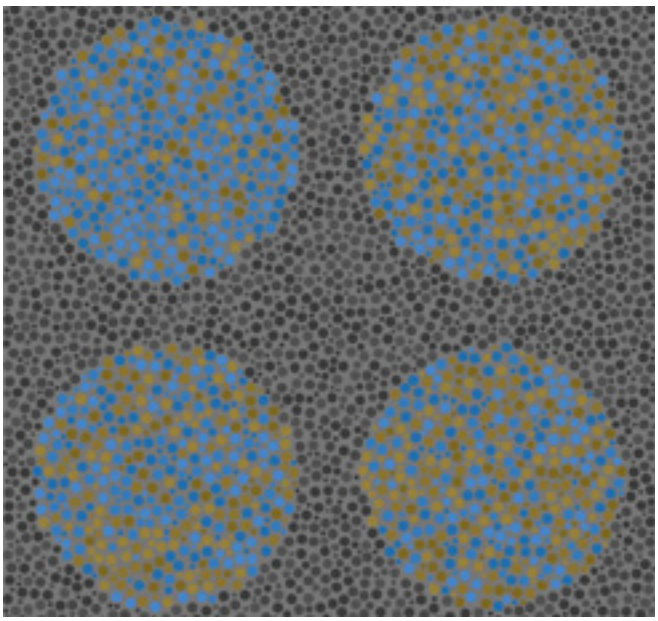
A decreased ability to distinguish between colours can occur in both eye (e.g. glaucoma) and systemic (e.g. Parkinson's) diseases. Because of this, measuring a person's colour discrimination ability can be an important tool in both testing for, and monitoring the progression of, diseases. Although commercial computer displays can render colours accurately, they do have limitations for performing clinical assessments of colour vision. Here we will investigate a different type of colour vision test aimed at overcoming these limitations, with the hope of making accurate colour vision assessment cheaper and more accessible, and potentially available via telehealth services.

PROJECT 2: DO THE MECHANISMS THAT PREVENT OUR NOTICING SMALL EYE MOVEMENTS IMPROVE OUR ABILITY TO JUDGE SMALL MOVEMENTS IN THE WORLD?

Even when we stare intently at a small target, our eyes are constantly in motion. This results in images that continuously move on our retina. Powerful perceptual stabilisation mechanisms prevent our noticing this motion, however. Whilst this means our world doesn't appear to incessantly jiggle around, does this actually improve our ability to see things? This project will investigate whether perceptual stabilization mechanisms improve our ability to do a very common task – making fine judgement of relative motion between objects in the world.

SELECTED PUBLICATIONS:

1. Park ASY, Bedggood PA, Metha AB, Anderson AJ (2019). The influence of perceptual stabilisation on perceptual grouping of temporally asynchronous stimuli. *Vision Res* 160:1-9.
2. Sepulveda JA, Anderson AJ, Wood JM, McKendrick AM (2020). Differential aging effects in motion perception tasks for central and peripheral vision. *J Vis* 20(5):8.



OPO

THE RETINAL OBSERVATORY

(IMAGING CELLULAR STRUCTURE AND FUNCTION IN THE LIVING HUMAN RETINA)

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The broad research aim of the Retinal Observatory is to observe the structure and function the living retina on the microscopic scale, so as to figure out what it is doing and how. We work collaboratively with other groups in the Department and throughout the University to observe how the retina works under normal circumstances, and how this becomes compromised in sight-debilitating diseases such as diabetes and inherited retinal degenerations. To achieve these aims, we combine a range of investigative tools including high-resolution non-invasive retinal imaging, psychophysics, and computational modelling.

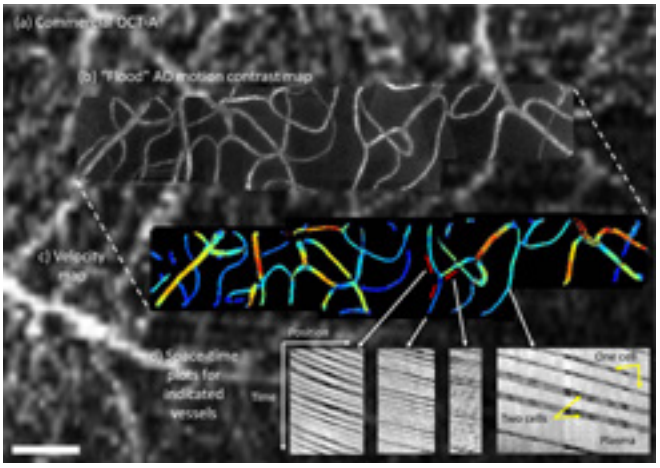
Our current research projects make use of high speed, multi-spectral adaptive optics to visualize the smallest neurons and blood vessels that is possible to see in in living human eyes. We study the dynamics of blood flow and oxygen exchange at the level of individual red and white cells, and the cascade of optical and physiological events that occur when a photoreceptor interacts with light.

This requires a multi-disciplinary approach and so we welcome motivated students across all fields (e.g. Mathematics, Physics, Computer Science, Engineering, Biology, Psychology), who are interested in contributing to our innovative programs of research.

PROJECT 1: KEEPING THE EYE ALIVE: CHARACTERIZING THE PULSATILE NATURE OF SINGLE RED AND WHITE BLOOD CELL FLOW THROUGH RETINAL CAPILLARY NETWORKS

With newly-developed adaptive optics (AO) retinal imaging, it is now possible to visualize the finest capillaries in the eye and watch the passage of single red and white blood cells through its fine web of vascular pipes. These are the networks that keep your retina healthy, and which fail in diseases such age-related macular degeneration and diabetes. The exact details of blood flow patterns have not yet been fully documented – even in healthy eyes – because blood flows very quickly. Also, because the retina is designed to be transparent, it has been difficult to obtain high contrast images without risking light damage. However, with the recent lifting of these technical issues, a novel project emerges to characterize aspects of normal flow such as: cell deformability during flow; variation in flow velocity through different parts of the network; and the influence of the cardiac cycle on flow pulsatility.

This project would suit Honours Students and Graduate Researchers who wish to learn about and apply optical and image processing skills to questions of basic human physiology with immediate clinical applicability.

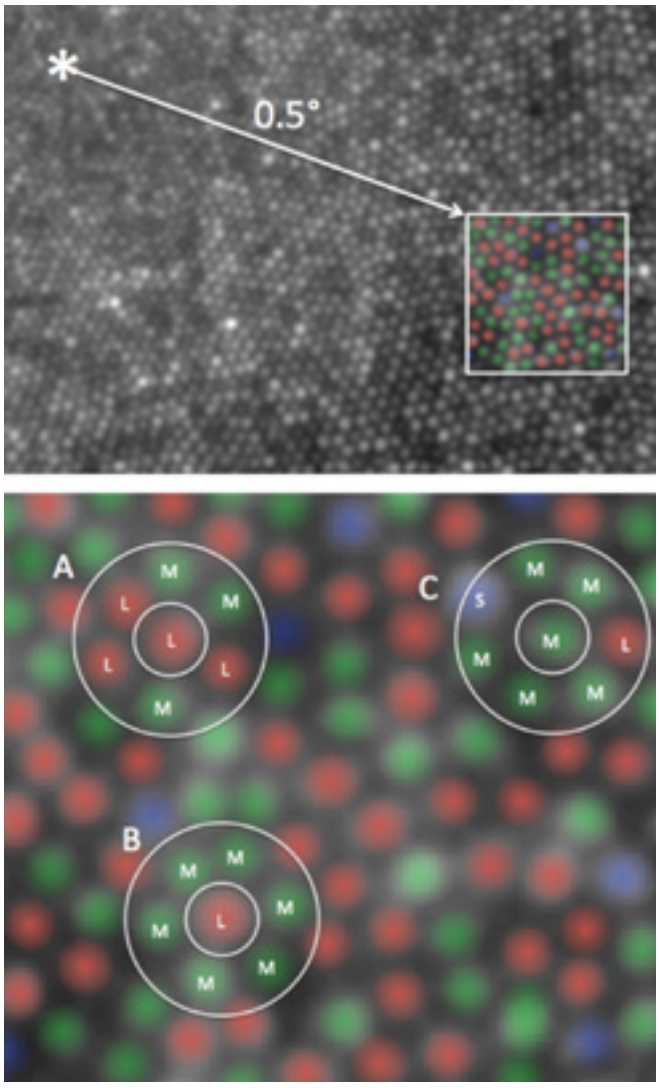


Tracking single-file blood cell flow though the retinal capillary network

PROJECT 2: WIRING THE RETINA FOR HUMAN VISION - A SINGLE-CELL BEHAVIOURAL APPROACH

The normal human retina is tiled with a mosaic of about 110 million rods and 6 million cone photoreceptors of 3 types that are sensitive to long (L), middle (M) and short (S) wavelengths of light. These 116 million photoreceptors converge to a mere 1 million axons that form the optic nerve connecting the eye and brain. The retina itself is responsible for much more than image detection, but is involved in substantial processing of visual information as well!

Using psychophysical methods to record behavioral responses to stimulating either single cells or specific cell arrangements, this project aims to establish precisely how signals from 3 types of cone photoreceptor are organised within the receptive fields of retinal ganglion cells whose fibers exit the eye, and how this impacts the information conveyed for spatial and colour perception.



Targeting single cone photoreceptors to investigate inputs to midget ganglion cells

PROJECT 3: IMPROVING THE EFFICIENCY, ACCURACY AND ROBUSTNESS OF HUMAN VISUAL PERFORMANCE MEASURES

Measurements of human visual performance are important both to understand the basic science behind vision and for diagnosis of blinding eye diseases. The methods currently used to measure visual performance in the clinic and laboratory are time-consuming, which limits the amount of information that can be gained in a given test session. This honours project will evaluate the use of alternate testing strategies designed to improve test efficiency, and determine whether such improvements can be obtained whilst avoiding the introduction of inaccuracy or bias. Specifically, the project asks whether: 1) the reported degree of certainty of participant's responses be used to determine visual threshold more quickly than assessing the accuracy of responses alone; and 2) the degree to which cueing participants to direct their attention to a smaller part of the visual field can improve the reliability of their responses. This information may have immediate clinical applicability for improving standard clinical perimetry (visual field testing) for diseases such as glaucoma and maculopathy, and also for making more efficient laboratory investigations of precise retinal cell sensitivity.

RECENT RELATED PUBLICATIONS FROM OUR TEAM:

1. Bedggood, P., & Metha, A. (2020). Adaptive optics imaging of the retinal microvasculature. *Clinical Experimental Optometry*, *103*(1), 112-122.
2. Duan, A., Bedggood, P. A., Metha, A. B., & Bui, B. V. (2017). Reactivity in the human retinal microvasculature measured during acute gas breathing provocations. Scientific reports, 7(1), 2113.
3. Bedggood, P., & Metha, A. (2013). Optical imaging of human cone photoreceptors directly following the capture of light. *PloS one*, *8*(11).

VISUAL AND COGNITIVE NEUROSCIENCE LABORATORY

LABORATORY HEAD

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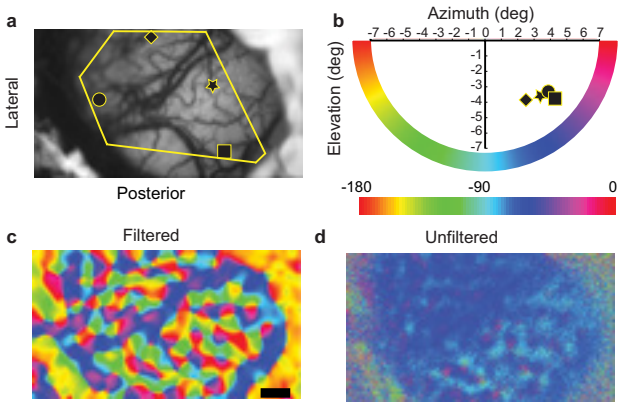
Summary of lab interests: Our laboratory is interested in understanding the neural basis of visual perception, attention and memory.

PROJECT 1: FUNCTIONAL MICROCIRCUITRY OF THE VISUAL CORTEX

Different areas of the cerebral cortex have fairly similar morphological structures regardless of their specific functions, suggesting that there is a universal cortical microcircuit which is involved in transforming the inputs.

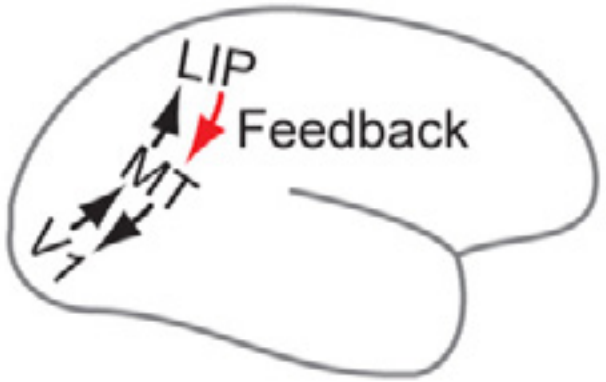
Understanding this microcircuit is important to understanding how the brain makes sense of the external world. In our lab, we examine the microcircuit of the primary visual cortex in anaesthetised cats and macaques, to shed new light on this problem. In these studies, we use a combination of single electrodes, multi-electrode arrays and optical imaging of intrinsic signals to examine the cortical inputs, responses of individual neurons and groups of neurons, to shed new light on this problem.

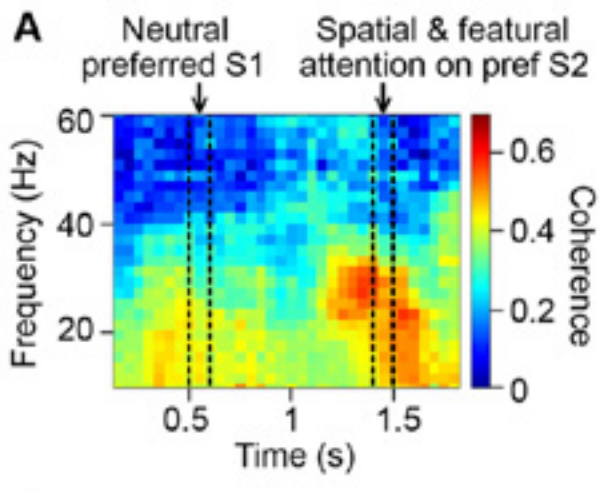


Orientation Domain Maps

PROJECT 2: NEURAL MECHANISMS OF TOP-DOWN ATTENTION AND PREDICTIVE CODING

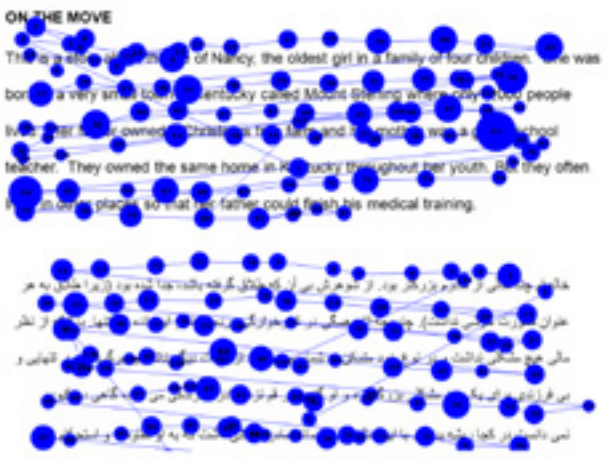
How does the brain manage to attend to a specific object or region of visual space when it is confronted with innumerable objects? How are we able to pick out a face in a large crowd, often so effortlessly? Such focussing of attention is known to involve some specific areas of the brain, but how these interact with each other has been largely unknown. In these experiments on trained macaques, we record from multiple brain areas implicated in visual attention, in order to characterise the distributed processing that occurs with attention. With these experiments, we also seek to test an influential new model that suggests that the brain makes conscious or unconscious predictions about what it expects to see in the external world and updates these expectations using any mismatches with the sensory inputs.





PROJECT 3: VISUAL ATTENTION, READING AND DYSLEXIA.

The basic cause of specific reading disability, commonly known as dyslexia, has been a matter of intense debate for decades. Reading is a relatively recent activity in human history and so it is very unlikely that humans have evolved a specific brain region or circuitry devoted to reading, but we probably use for reading brain functions that evolved for a different purpose. Our lab has been working on the idea that one such critical brain function is the visuo-spatial attention network usually used in focussing attention at a visual field location for object identification. We recently found the visual attention efficiency to differ substantially between people and it is related both to reading speeds and to the functional size of the primary visual cortex. We are now exploring these relationships further using visual psychophysics and functional brain imaging in the dyslexic population and also comparing reading of scripts written from left to right (as in English) with those written from right to left (as in Farsi).



PUBLICATIONS OF THE TEAM RELEVANT TO CURRENT INTERESTS:

1. Archer K, Pammer K & Vidyasagar TR (2020). A temporal sampling basis for visual processing in developmental dyslexia. *Front Human Neurosci*., Vol. 14, Article No.213. doi: 10.3389/fnhum.2020.00213.
2. Mohan YS, Jayakumar J, Lloyd EKJ, Levichkina E & Vidyasagar TR (2019). Diversity of feature selectivity in macaque visual cortex arising from limited number of broadly-tuned input channels, *Cerebral Cortex*, 29, 5255-5268.
3. Vidyasagar TR & Levichkina E (2019). An Integrated Neuronal Model of Claustral Function in Timing the Synchrony Between Cortical Areas. *Front Neural Circuits*, Vol. 13:3. doi: 10.3389/fncir.2019.00003.
4. Kermani M, Verghese, A, Vidyasagar TR (2018) Attentional asymmetry between the visual hemifields is related to habitual direction of reading and its implications for debate on cause and effects of dyslexia. Dyslexia. 24(1):33-432.
5. Levichkina E, Saalmann YB, Vidyasagar TR (2017) Coding of spatial attention priorities and object features in the macaque lateral intraparietal cortex. Physiological Reports. 5(5).
6. Vidyasagar TR, Eysel UT (2015) Origins of feature selectivities and maps in the mammalian primary visual cortex. Trends in Neurosciences. 38(8), 475-485.
7. Jayakumar J, Roy S, Dreher B, Martin P & Vidyasagar TR (2013). Multiple pathways carry signals from short wavelengths-sensitive ("blue") cones to the middle temporal (MT) area of the macaque, J. Physiol (Lond), 591, 339-352.
8. Vidyasagar TR & Pammer K (2010). Dyslexia: a deficit in visuo-spatial attention, not in phonological processing. Trends Cognitive Sci., 14(2):57-63.
9. Saalmann YB, Pigarev IN, Vidyasagar TR (2007) Neural mechanisms of visual attention: how top-down feedback highlights relevant locations. Science 316(5831), 1612-1615.

VISION OPTIMISATION LABORATORY

LABORATORY HEAD

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Summary of lab interests: In recent years, there have been a number of interventions developed for vision loss and blindness. From gene therapy to bionic eyes, all treatments require thorough evaluation of visual function pre- and post-intervention, as well as an understanding of the impact of the treatments on a person's life.

Our team works on clinical vision and psychosocial assessments of people who receive such vision interventions. We have developed and run clinical studies for retinal prostheses (bionic eyes), gene therapy, and other low vision aids (including sensory substitution devices). Our aim is to ensure that every person is able to make the most of the vision they have.

The lab maintains strong collaborations with engineers (University of Melbourne, Bionics Institute, Swinburne University, Cornell University USA), neurologists (Harvard University, USA), ophthalmologists (Royal Victorian Eye and Ear Hospital, Centre for Eye Research Australia), visual function experts (Oxford University, UK) and basic scientists (University of Melbourne) to assist in the development of new treatments.

Currently, we are collaborating on a project to develop Australia's first ocular gene therapy for an inherited retinal disease; designing new software algorithms for electronic and audio-based low vision aids; developing novel imaging techniques to identify raised intracranial pressure and running natural history studies to identify biomarkers of retinal degenerative disease. We are also involved in industry-sponsored clinical trials, including gene therapy for age-related macular degeneration, and an oral anti-oxidant for Usher syndrome, the most common cause of dual vision and hearing loss.

PROJECT 1: DEVELOPMENT OF NEW VISION TESTS FOR VISION RESTORATION CLINICAL TRIALS

This project, in collaboration with clinicians at the University of Oxford and ophthalmologists from the Centre for Eye Research Australia, will develop and validate new methods of measuring low vision in patients who may be eligible for treatments such as gene therapy and stem cells. At present, there is a lack of gold standard test protocols for low vision testing, and this project will provide important data on the validity of new tests. For example, one avenue of interest in this area is colour vision measures.

PROJECT 2: NATURAL HISTORY OF INHERITED RETINAL DISEASES

A large study in our group is focusing on the collection of data on the natural history of inherited retinal diseases in Australia and New Zealand. A number of research projects into imaging biomarkers, genotype/phenotype correlations and visual function measures in this population are available.

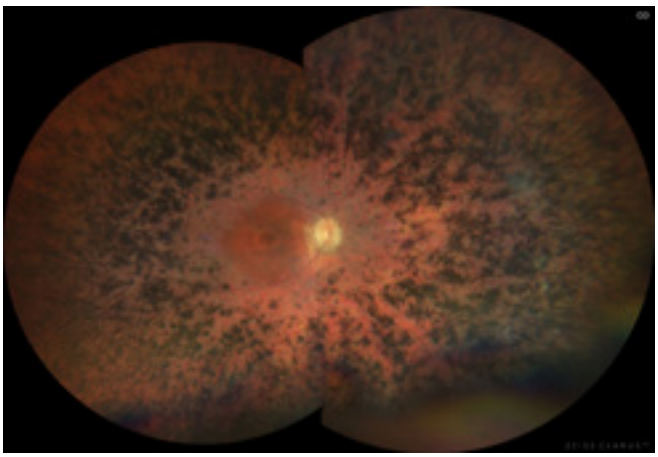

Figure: A retinal fundus photo of a person with X-linked retinitis pigmentosa, a form of inherited retinal disease that we focus on in our research.

PROJECT 3: EVALUATION OF ADVANCED LOW VISION TECHNOLOGIES

Historically, low vision aids were low-tech, such as magnifying glasses and high-powered spectacle lenses. However, recent advances have led to a proliferation in high-tech alternatives, such as the iPhone, text-to-speech software and spectacle-mounted camera systems. This research program is investigating the efficacy and uptake of these technologies, and comparing to the more traditional options for patients with conditions such as age-related macular degeneration.

RECENT RELATED PUBLICATIONS FROM OUR TEAM:

1. Liu Z, Ayton LN, O'Hare F, Arslan J, Hu ML, Noar AP, Wang J-H, Hickey DG, McGuiness MB, Vincent AL, Chen FK, Edwards TL. *Inter-eye symmetry in Bietti Crystalline Dystrophy*. American Journal of Ophthalmology 2021; Published online 17 July 2021.
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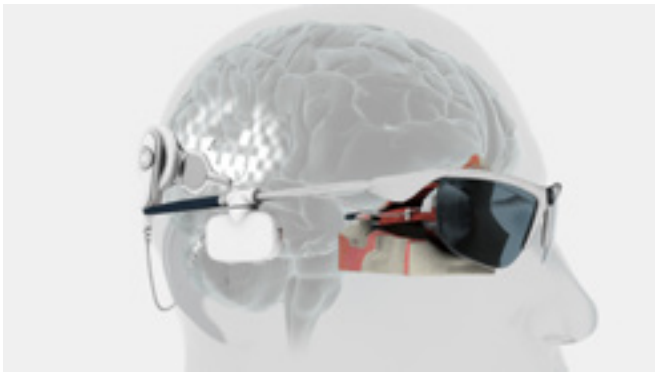
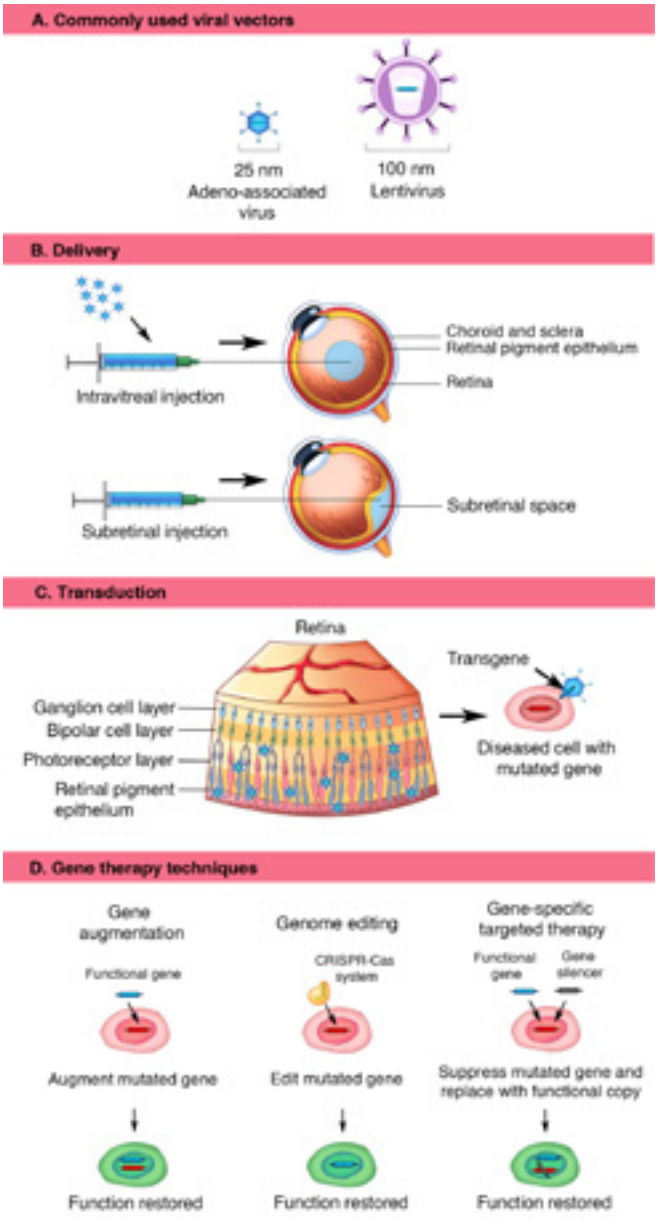
6. Ayton LN, Barnes N, Dagnelie G, Fujikado T, Goetz G, Hornig R, Jones BW, Muqit MMK, Rathbun DL, Stingl K, Weiland JD, Petoe MA. *An update on retinal prostheses.* Journal of Clinical Neurophysiology 2020; 131(6):1383-98.





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