Research Projects
2019
(Honours, Masters and PhD)
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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 83447004 trv@unimelb.edu.au or the Departmental Graduate Researcher Coordinator for PhD and Master of Philosophy related queries, Prof Algis Vingrys on 83447001 algis@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

Department of Optometry and Vision Sciences
Clinical Psychophysics Unit

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https://healthsciences.unimelb.edu.au/research-groups/optometry-and-vision-sciences-research/clinical-psychophysics-unit
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 aging. 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, human electrophysiology and human brain and ocular imaging. Our work is highly collaborative with colleagues from ophthalmology, psychology, physiotherapy, neurology and neuroimaging.

Project 1: Does exercise impact on visual system plasticity?
Recent evidence shows that exercise alters brain neurochemicals. Specifically, exercise alters the balance between cortical inhibition and excitation. This study will test whether short bursts of exercise actually change visual performance, using measures of visual perception that are reliant on the balance of inhibition and excitation in the visual pathways.

Illustrative visual stimuli used to probe visual perception in people with migraine

Project 2: Visual perception in migraine
People who experience migraine often report sensitivity to certain high contrast visual environments. The mechanisms underpinning this sensitivity are not well elucidated, although a wealth of literature points to involvement of the visual pathways during migraine events. Our research explores visual processing in people with migraine, using visual perceptual tasks designed to localise anomalies within the visual pathways. This project will help shed light on the neuroanatomical basis of visual symptoms in people with migraine.
Project 3: Does migraine influence eye health?

New non-invasive imaging methods allow measurement of blood vessel structure in the retina, in addition to measures of neural tissue at high resolution. Migraine is a common neurological disorder that can result in changes to peripheral vascular responses. There is long-standing debate regarding the extent to which repeated migraine events cause changes to the retina over time. The aim of this project is to determine whether state-of-the-art eye imaging techniques reveal anatomical differences in the eye in people with migraine, and whether there is a relationship with migraine severity or frequency.

Recent related publications from our team:


Optological Laboratory

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Summary of lab interests: 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: The influence of reward on where we look
Bray & Carpenter (2015: European Journal of Neuroscience) have shown that we are quicker to initiate an eye movement toward a location that provides reliable information about the location of a future target. This is consistent with the idea that acquiring information is the “reward” associated with eye movements, in contrast to the sometimes unnatural rewards – such as money or food – used in many experiments. Their method raises several questions about the nature of this information reward and how it is processed by eye movement centres in the brain. This project will investigate some of these questions.
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 Publication:


The Retinal Observatory

(Imaging cellular structure and function in the living human retina)

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Summary of lab interests: Our broad research aim is to understand the fundamental workings of the living retina on the microscopic scale: how this works normally and how this becomes compromised in sight-debilitating diseases such as diabetes. We combine a range of investigative tools including high-resolution non-invasive imaging, psychophysics, computational modeling and electrophysiology.

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 living human eyes. We study the dynamics of flow and oxygen exchange at the level of individual red blood 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 program of research.

Project 1: Characterizing single red and white blood cell flow through human retinal capillary networks
Adaptive optics (AO) retinal imaging now permits the spatial resolution to visualize the finest capillaries in the eye and the temporal resolution to observe passage of single red and white blood cells through the smallest arteriolar and venular retinal networks.

The fine details of retinal blood flow patterns has not yet been fully documented, rendered difficult because of the high speeds of cell flow, the inherently low contrast of cell images, and limited imaging durations imposed by photo-toxicity of the imaging light itself. With the recent lifting of these technical issues and the ability to track passage of individual red and white blood cells, a novel project emerges to characterize aspects of normal flow such as: cell deformability as a function of vessel calibre; variation in flow velocity through different parts of the network; and the influence of the cardiac cycle on flow pulsatility.

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, an exciting ARC-funded project exists 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.

Project 3: Methods to improve the measurement of visual performance

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 human 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 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:


Ocular Physiology Laboratory

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

**Summary of lab interests:** Our laboratory is interested in understanding the causes of retinal and optic nerve injury in diabetes and glaucoma.

**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 is diminished.

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 an chronic model of intraocular pressure elevation. We will study ganglion cell responses to stress by quantifying their function and relating this to changes in dendritic morphology and expression of membrane pressure sensors.

**Project 2: Studies of retinal vascular autoregulation**

The retina and brain are the most highly energy demanding tissues in the body. High neuronal density comes at the expense of a lack of storage of metabolic substrates. These tissues are thus dependent on the maintenance of a stable blood supply. In the retina there are three major vascular beds (superficial, intermediate and deep) that entirely locally controlled. This control system is known as vascular autoregulation, and involves not only the cell lining the blood vessel walls (endothelial cells) but also 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 both animal models and in humans. We will determine how specific cells impact the vascular response to changes in pressure.
Project 3: Developing a clinical test of vascular autoregulation

Using optical coherence tomography we will image the response to flickering light of the inner retinal vasculature. In human subjects, in response to flickering light, the superficial layer shows more vessel dilation. We hope to use this approach as the basis for a clinical test of vascular autoregulation to detect early diabetic and glaucomatous changes.

Recent related publications from our team:


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: Assessing novel compounds for diagnostic retinal imaging
A key recent finding in Alzheimer’s disease (AD) research is that the toxic form of amyloid-beta (Aß) lies not in the amyloid plaques but in the soluble oligomers which precede plaque formation. However, it is not yet possible to detect oligomeric Aß in-vivo. The aim of this project is to apply an anti-oligomer-antibody to the retina, an out-pouching of the central nervous system. Given the clear optics the eye, we will fluorescently tag our antibody and directly image them in living animals. The capacity to develop early and sensitive biomarkers for AD is pivotal given for successful development of treatments.

Functional and structural assessment of retinal health in animals models of neurodegenerative disease
**Project 2: Characterising ocular measures in an alpha-synuclein model of Parkinson’s disease**

The retina’s electrophysiological response to flashes of light have been shown to be highly discriminating of those with Parkinson’s disease from controls. These changes are thought to be driven by dopamine. Importantly, such anomalies are ameliorated by L-DOPA therapy. Dopamine has multiple roles in the retina including modification of light adaptation and alteration to ON-OFF responses in bipolar cells. Thus by utilising electroretinography techniques which target these dynamic responses may potentially provide a more sensitive marker of dopamine abnormalities in the preclinical and clinical setting. This project aims to evaluate whether this is the case in a transgenic alpha-synuclein mouse model of Parkinson’s disease.

**Project 3: Developing iPad home-monitoring platforms for Alzheimer’s disease**

A key goal in Alzheimer’s disease is early detection. This is thought to be an essential step towards developing effective treatments as clinical trials in the last decades have failed in part because they occur too late in the disease process when irreversible damage has already occurred. Thus biomarkers which are simple and can be measured repeatedly with short inter-test times may be useful monitoring tool for those patients at risk of the disease. Current AD evaluation is restricted to assessment in a clinical environment and thus the interval between assessments is commonly 6-12 monthly or longer. Assessment with a tablet device such as an iPad (Apple, Inc. Cupertino, CA) enables low-cost portable assessment with proven suitable luminance range and spatial resolution for perceptual testing. This project aims to develop a suite of ipad tests that could assist with early diagnosis or monitoring of AD patients.

**Project 4: Comparing conventional and portable assessment of retinal electrophysiology**

Emerging evidence indicates that changes to the electrical response from the retina (electroretinogram) may reflect changes in cortical disease such as Parkinson’s disease. Studies have shown characteristic dampening of the electroretinogram (oscillatory potentials, a, b-wave) in Parkinson’s disease patients that reverse with current gold standard treatment with L-DOPA. However, one barrier to being more widely accepted as a clinical tool of drug efficacy is that conventional electroretinography assessment has to be conducted in a specialised laboratory by a highly trained clinician. Portable hand-held ERG devices have recently become available which have further improved comfort and speed for the patient as well as greater ease of use for the clinician. In a control group of patients, this study aims to compare test retest variability of conventional and portable electroretinogram systems to determine whether the portable device may be useful for disease cohorts.

**Recent related publications from our team:**


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**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 corneal appears structurally normal, with the epithelial cells appearing healthy and tissue architecture appearing clear. 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 students.
Project 2: Novel strategies to accelerate corneal nerve regeneration in mice

Damage to corneal nerves can occur through injury to the epithelium or even the long-term use of some commonly prescribed eyedrops. This project will involve testing whether two novel, topically applied therapeutic agents can reduce corneal nerve damage and improve nerve regeneration rates in the mouse cornea using experimental models of sterile injury and eyedrop-induced neurotoxicity. This project will involve animal handling, clinical imaging, ex vivo confocal microscopy, protein assays and 3D image reconstruction and image analysis.

This project would be suitable for Masters or PhD students.

Recent related publications from our team:


Anterior Eye, Clinical Trials and Research Translation Unit

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Summary of lab interests: The Anterior Eye, Clinical Trials and Research Translation unit adopts an integrated approach to research in ocular disease, combining clinical, laboratory and behavioural science as a foundation for evidence-based practice, to improve clinical outcomes.

We possess advanced clinical and research expertise, particularly in the areas of anterior eye disease (including therapeutic and contact lens clinical trials, and investigating novel tear film biomarkers as measures of ocular and systemic health), and research translation (including the development and testing of interventions to improve research dissemination and implementation in clinical practice). We also collaborate closely with Dr Holly Chinnery, who leads the Corneal and Ocular Immunology laboratory, in the Department of Optometry and Vision Sciences.

Anterior eye and clinical trials: Our anterior eye research combines sophisticated clinical techniques (including optical coherence tomography, corneal confocal microscopy (Figure 1) and tear osmometry) with basic science investigations (e.g., immunological and proteomic analyses of the tear film), to characterise the ocular inflammatory response during disease (e.g., diabetes) and contact lens wear. A further research focus is the investigation of novel therapeutic treatments for dry eye disease and contact lens technologies, including their application for myopia control.

Research translation: Another major focus of our work is the translation of research into clinical practice. We have developed a Macular Degeneration Clinical Care Audit Tool (MaD-CCAT) for optometrists to audit the clinical care provided to patients with age-related macular degeneration against national guidelines. Our group is also currently undertaking several national and international collaborative projects relating to the development of clinical tools and systematic reviews, in areas such as dry eye disease and age-related macular degeneration.

In addition, we have recently developed a free, online platform (in collaboration with Dr Michael Pianta) called CrowdCARE, (Crowdsourcing Critical Appraisal of Research Evidence crowdcare.unimelb.edu.au), which uses crowdsourcing to support evidence-based practice. Early data support the capacity for this system to redefine how healthcare practitioners 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: Investigating novel ocular biomarkers of peripheral nerve health

Current major barriers to timely diagnosis of peripheral neuropathy are the reliance on specialised neurological tests and the poor diagnostic yield of existing methods, which can fail to detect asymptomatic and subclinical neuropathy. Notably, small nerve fibres can be non-invasively visualised in the cornea. In addition, the tear film, with continuous turnover and non-invasive sampling, is a complex biological fluid with unique capacity for biomarker interrogation. The aim of this project is to investigate whether novel anterior ocular biomarkers can be used as a surrogate measure of the health of peripheral nerves. This project will involve participant recruitment, clinical examinations, immunologic and proteomic tear analysis techniques, and digital image analysis. It is suitable for Masters and PhD students.

Project 2: Is crowdsourcing a valid approach to evaluating research quality?

Evidence-based practice is a dominant paradigm in healthcare that aims to deliver the highest quality of patient care. A key component of the evidence-based practice process is critically appraising the quality of the research literature; this is a potentially time-consuming task, which is an established barrier to the implementation of evidence-based practice by clinicians. Using the 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. This project will engage clinicians, researchers and students to contribute critical appraisals, and involve considerable data evaluation and statistical analysis. It is suitable for Honours and Masters students.

Project 3: Cognitive biases in clinical decision making

Cognitive biases, involving systematic thinking errors that impede rational judgement, can impact on health practitioners’ clinical decisions. However, no research has specifically examined the role of cognitive biases in the clinical decision-making of eye care professionals. This project will investigate how different types of cognitive bias influence clinical decision-making in optometric practice, and potentially investigate methods for countering these biases. Outcomes will inform future research into developing interventions to mitigate common bias(es) in practicing eye care clinicians and students. This project will involve the creation of clinical vignettes, survey/questionnaire development using an online platform, participant recruitment, and data analysis. Clinical experience would be advantageous, but is not essential. The project is suitable for Honours, Masters and PhD students.
Visual and Cognitive Neuroscience Laboratory

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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.

Project 2: Neural Mechanisms of Top-down Attention
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 focusing 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.
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).

Recent related publications from our team:


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Information Session
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Research Projects 2019

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