# York University's Centre for Vision Research

CVR is one of the premier vision research centres in the world investigating the mechanisms and applications of vision in the broadest sense. **Professor Laurence Harris**, Director, offers a snapshot of its pioneering work that covers a wide range of health issues from stroke to autism

**To begin, can you give a brief outline of the Centre for Vision Research (CVR) at York University?**

CVR is an international leader in human and machine vision research. We are the largest such centre in Canada and have been ranked by external reviewers as one of the top five vision research centres in the world. Our mandate is to pursue world-class, interdisciplinary research and training in the broadly defined visual sciences and their applications.

The Centre was founded by Dr Ian Howard in 1992. Uniting researchers from psychology, computer science and engineering, biology, kinesiology and health science, work at CVR is highly interdisciplinary and collaborative, rooted in a fundamental research programme that merges techniques in human psychophysics, visual neuroscience and computational theory.

**What areas of research is the Centre renowned for?**

CVR is home to a rich history of scientific discovery and technological innovation with real-world consequences. Our health research tackles vision-related problems associated with strokes, migraine, neurological disorders, autism and visual deficits in Canada's ageing population. Vision technology application areas include medical and assistive devices, visual security, search-and-rescue, 3D film, and augmented reality systems used in collaboration with NASA and the aerospace industry.

Faculty hold Canada Research Chairs in Visuomotor Neuroscience and in Computational Vision, and two are Fellows of the Royal Society of Canada. Several CVR members have received important Canadian and international awards for their research including Sloan, Humboldt and Killam Fellowships. We have two Polanyi winners and a winner of the Staecie prize, which are the top Canadian awards for young scientists. Our members have been recognised by international societies including the Canadian Image Processing and Pattern Recognition Society, the Association for Research in Vision and Ophthalmology (Kupfer and Proctor awards), the Japanese Society for the Promotion of Science, the International Neural Network Society (Helmholtz award), the American Academy of Optometry (Prentice medal) and the Royal Society of Canada (Dawson medal).

**Could you highlight the benefits of CVR's strong interdisciplinary approach?**

The solution to the complex problem of how we process visual information cannot be reached except through an integrative approach. For example, interdisciplinary synergies have been formed between neurophysiologists, who are uncovering the neural basis for attention, and computer scientists who incorporate the brain's solutions into 'neuromorphic' artificial models of attention. Virtual reality, in which our Centre excels, is an excellent example of how computer scientists produce state-of-the-art systems in collaboration with psychologists, who design experiments using these technologically advanced systems.

**What leading-edge facilities does the Centre have to offer?**

We have a fully-immersive, six-sided virtual reality room: one of only a few in the world; a calibrated facility for stereo and motion imaging; multiple mobile robot platforms; methods for tracking eyes, reaching and whole body movements; and one of the largest electrophysiological recording facilities in Canada. Our magnetic resonance imaging (MRI) facility houses a state-of-the-art 3 Tesla MRI scanner equipped with visual and auditory display devices as well as eye tracking, physiological and behavioural monitoring equipment. We also have a custom-built tumbling room which can rotate around a person who can also be rotated. A team of NASA astronauts used this room to train before one of the shuttle missions. A room built on its side provides a convincing simulation of zero gravity exposure.

**With whom does the Centre collaborate and what benefits have such partnerships brought to your research?**

Our 22 adjunct members, with whom we collaborate frequently, include top vision researchers from other establishments such as McMaster University, the University of Toronto, Southlake Hospital, the Toronto Rehabilitation Institute and the Hospital for Sick Children in Canada, and the University of London and University of Oxford in the UK. Our collaborations are often formalised, as with the Canadian Action and Perception network, or through joint funding initiatives.

## CVR in numbers

**30** faculty members

**18** postdoctoral fellows

**14** research associates

**5** research assistants

**78** graduate students

**22** adjunct faculty appointments from other research establishments

**6,000** $m^2$ lab space

Assessing a Parkinson's patient's use of vision for balance and orientation.

Our partnerships with research-based hospitals, including The Hospital for Sick Children, the Toronto Rehabilitation Institute, and Toronto Western Hospital (TWH), permit access to established clinical databases and further technical expertise. CVR members are uniquely situated to recruit rare patient populations, such as individuals who have experienced removal of one eye in early life, or patients with multiple sclerosis, stroke, epilepsy, cataract, amblyopia, glaucoma and Parkinson's disease. Our researchers are collaborating with neurosurgeons at TWH to uncover neural signatures of visual processing in epileptic patients and to develop treatments to improve visual memory in Alzheimer's patients.

Collaborations and partnerships like these are essential in allowing us to expand our basic science research into real-world applications.

**How is the Centre funded?**

York University supports some aspects of the administration of the Centre while the major support comes from the Canadian Institutes for Health Research (CIHR) and the Natural Sciences and Engineering Research Council (NSERC). We also receive funding from the Canadian Foundation for Innovation (CFI) and several other sources including industrial contracts with companies such as IBM and organisations like the Canadian Space Agency. Since its formation in 1992 the CVR has attracted grants from both Canadian and international sources in excess of CAD $100 million including over $8 million from CFI. We have also benefited from the generosity of several private donors, especially for our health-related work.

**Your recent Interactions in Vision conference took place in June. What is the aim of the event?**

Since the Centre was founded we have held biennial vision conferences, most of which have been published as books by Cambridge University Press (CUP), Oxford University Press (OUP) and Springer Verlag. We hand pick outstanding scientists chosen not only for their scientific prowess but also for their engaging style. Formal talks are buttressed by submitted posters.

Each CVR conference not only brings together international scientists but also develops a specific theme. In some cases, the theme derives from a particular research area within vision science, eg. computation vision or visual plasticity; in other cases, the theme derives from a celebration of the career of one of our more senior members. The conference this year was based around the careers of two of our members who are about to retire from York University, past director Dr Hugh Wilson and founding member Dr Marty Steinbach. Previous conferences have celebrated the careers of our founder, Dr Ian Howard (*Levels of perception*, CUP) and DM Regan (*Seeing Spatial Form*, OUP). Our conferences help make the world aware of the careers of these influential scientists, whilst also providing a stimulating environment for our younger members.

**What is the Centre doing to attract young people to take up vision research?**

Training the next generation of vision scientists is one of our most important contributions. Our reputation is well known to other vision scientists and postgraduate trainees, but making undergraduates aware of our presence is harder. We run an annual summer school (www.cvr.yorku.ca/cvrss) showcasing our Centre (our breadth allows us to cover virtually all aspects of vision research in-house) to prospective graduate students, giving them hands-on experience across a broad range of vision research. Our NSERC CREATE training programmes provide support for internships within and outside York University. We are currently training 78 graduate students, and students from different labs are encouraged to move freely between the labs both socially and scientifically.

## Focus areas of CVR:

### ACTIVE VISUAL SEARCH:

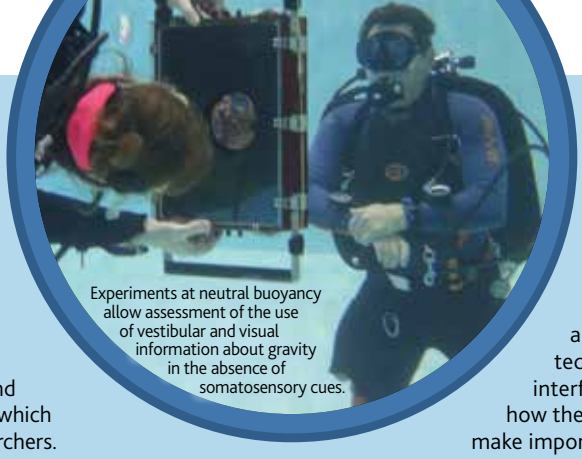
The Centre has elucidated brain mechanisms involved in determining 3D eye and head orientations, and the active role that our changing gaze plays in coding and interacting with visual scenes. Researchers have developed strategies than can be used by remote cameras and robots to search for faces and to aid search-and-rescue operations, for example. CVR holds a number of patents on biologically-inspired attentive-sensing computer vision technology. Advances in attentive-sensing technologies coincide with the recent explosion in 3D geo-databases, which provide large-scale 3D models of urban environments (eg. Google Earth).

### ENHANCING FACE AND OBJECT RECOGNITION:

Researchers at CVR study how faces and other social cues are processed by neural circuits, and the role that memory and attention play in influencing these perceptions both in neural and artificial systems. A computational model of human visual attention is used to enhance computer object recognition and forms the theoretical foundation for most machine vision realisations, including autonomous, visually-guided, robotic wheelchairs and companion robots for the elderly and infirm.

### VISION IN SPACE:

CVR's space-related projects include investigating changes in astronaut's perception in space and using this information to inform space craft design. The Centre has also developed robotic systems for guidance of planetary rovers.



Experiments at neutral buoyancy allow assessment of the use of vestibular and visual information about gravity in the absence of somatosensory cues.

The Centre hosts regular seminars on current topics of broad interest where guest speakers from around the world and CVR members are encouraged to come together and interact. Our in-house research retreats further facilitate interactions that bridge the breadth of expertise of our members. We also host a biennial international conference series which brings together people from all the relevant disciplines, and the prestigious Ian Howard lecture series which draw some of the world's top vision researchers.

**In light of Canada's ageing population, how are you tailoring your research to deal with age-related visual conditions?**

Many of our members are working on problems that concern the elderly. We have developed new diagnostic and measurement tools for Alzheimer's disease, where visuomotor abilities and visual memory are early and sensitive signs of disease progression. In addition to helping to detect symptoms of the disease, we are also involved in a collaborative effort to develop a treatment strategy using deep brain stimulation, with the hope of alleviating the memory deficits of Alzheimer's patients. A central problem in the healthy ageing population is the increased tendency to fall. We have recently been awarded a large CFI grant that will enable us to investigate the use of peripheral vision by the elderly and how it interacts with the sense of balance to prevent falling.

**What are your research targets for the future?**

Our aim is to be the world's leading vision research centre. Our multidisciplinary approach and formidable array of state-of-the-art facilities will allow us to continue to make groundbreaking contributions to the understanding of sensory processing and to how basic science is applied in the real world. We want to understand how people look at, recognise, understand, interact with and navigate objects in their surroundings. We then want to apply this knowledge to help alleviate visual dysfunctions, ranging from the inability to distinguish faces to problems with walking and balance in the elderly. We will continue to lead the development of computer systems that can read, identify and track faces, objects and events. We are also working on enhancements to virtual technology and the computer-human interface. In short, we want to understand how the brain works and to use this insight to make important contributions to visual health and technological innovations.

As we move further into the 21st Century, technology will increasingly rely on synthetic visual applications. The demand for visual health and assistance will only increase with our ageing population. In all respects, CVR is poised to play a key role as innovators in eye health and technology. Our vision is to reveal the fundamental mechanisms of our sensory processes and how they influence all aspects of our lives and functioning: we move forwards with confidence.

**www.cvr.yorku.ca**

### VIRTUAL REALITY:

The Centre uses virtual reality created by head-mounted helmets and immersive screen-based technologies to explore the effects of the visual environment on perceptions of orientation and self-motion, and to develop novel human-machine interfaces.

### 3D-VISION:

How we see in three dimensions has recently come to popular awareness with the rise of 3D technologies for film and television. To address how best to utilise these technologies, CVR has formed an interdisciplinary collaboration with members of the faculty of fine arts, 3D film and post-production companies and content creators. It is now a leading international centre for research on 3D film technology.

### CLINICAL APPLICATIONS:

Work on medical applications of visual science involves the use of multi-modal imaging techniques; preclinical models of neurological disorders; and psychophysical testing of both paediatric and adult patient populations to provide insight into the pathological substrate of visual impairment – a key step in the future design of therapeutic strategies. For example, CVR has examined how visual perception can be impacted by disease-related damage to neuroanatomical structures spanning the retina to the cortex. The Centre addresses issues associated with sensory loss, and how vision health is affected in patients with Parkinson's disease, multiple sclerosis and stroke. Other methodologies have been applied to the study of strabismus, migraine, autism, albinism and glaucoma. The Centre has also helped develop computer algorithms for modelling the 3D structure of the heart.