

# IQ

INNOVATION QUEST

Fall 2013

McMaster University's Research Newsmagazine

## Brainpower

IN THIS ISSUE:  
mind-blowing research



## Welcome

**Welcome back to IQ.** This issue provides an overview of the kinds of work we're doing in the area of neurotechnology, the backbone of a "neurotech" cluster being developed in Hamilton. It's an exciting initiative, harnessing our neuroscience knowledge and expertise to drive technology development.

McMaster's research expertise in this area spans the disciplines from humanities to health sciences; engineering to science. Our researchers are investigating virtually every aspect of the brain. They're looking at how this amazing organ develops and allows us to see and speak, how it organizes, controls and coordinates to perform tasks, how it's affected by injuries like concussions and diseases like Alzheimer's and mental illness. They are developing and improving technology with industrial partners and creating world-leading facilities, such as our state-of-the-art and one-of-a-kind LIVE Lab, part of the McMaster Institute for Music & the Mind.

While their work is diverse, they share a single goal: to advance our knowledge of how the mind, brain and body work together and to improve health and reduce the effects of disease and injury. Together, they are making great progress. I hope you enjoy their stories.



**Mo Elbestawi**

Vice-President, Research & International Affairs

■ On the cover: Mike Noseworthy, associate professor of Electrical and Computer Engineering and co-director of McMaster's School of Biomedical Engineering, also heads up the Imaging Research Centre at McMaster's Brain-Body Institute.

## INQUIRE

IQ is published by the Office of the Vice-President  
(Research & International Affairs)

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Printed in Canada 12/2013

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# IQ research matters

## KATHLEEN MARTIN GINIS The power of physical activity

**Alzheimer's disease (AD) affects 700,000 Canadians**, accounting for 64 per cent of all dementias, and the number is rising sharply. It's expected that as many as 1.4 million Canadians will be afflicted by 2031. The economic costs, from health care to lost earnings, are huge and growing, from \$33 billion this year to an estimated \$293 billion annually by 2040.

How do we reverse the trend and reduce the human and economic burden of this debilitating disease? The Ontario Brain Institute (OBI) is betting that exercise can play a key role, and it's funding a McMaster project to learn the best way to go about it.

The study will be led by kinesiology professor Kathleen Martin Ginis, a health and exercise psychologist and Director of McMaster's Physical Activity Centre of Excellence (PACE). This state-of-the-art exercise research and training centre is home to a collection of neuroscientists, physiologists and behavioral scientists whose aim is to improve the health and well-being of older adults and people with chronic disease or disability.

Martin Ginis knows a lot about physical activity and the disabled. She has spent the past 10 years studying the impact of exercise on adults with spinal cord injury (SCI), and testing interventions designed to increase their motivation and self-management skills.

Her work led her to launch SCI Action Canada, a national organization committed to developing and implementing new knowledge and interventions that enable Canadians with SCI to become more physically active.

"We know that daily physical activity levels are lower for people with physical or cognitive impairments," says Martin Ginis. "Often, this is not because they can't or don't want to exercise. It's just that there are many more obstacles in their path that prevent them from being physically active."

Most fitness centres, she points out, are geared to an able-bodied population. "They don't know what to do with someone who has physical or cognitive challenges. What kinds of exercise are appropriate? How much exercise is enough? How much is too much, and how will they know?"



Kathleen Martin Ginis

To aid doctors, physiotherapists, rehabilitation specialists, fitness instructors and the SCI community itself, Martin Ginis developed a set of exercise guidelines plus a practical resource, the SCI Get Fit Toolkit, complete with recommended activities, sample action plans, tips on how to stay motivated and avoid injury, and links to other web sites, including those that help users find fitness clubs geared to their special needs.

Launched in 2011, the guidelines were recently included in the Canadian Medical

Association's clinical guidelines for SCI. Requests for the Tool Kit number in the thousands, and the online version has been downloaded all over the world.

Martin Ginis has since repeated the process for adults with multiple sclerosis, with similar success. Her track record in translating evidence-informed knowledge on exercise and special populations out into the community is what caught the attention of OBI.

"No one else is doing this. Our SCI guidelines were not just the first for this population, they were the first for any disabled population."

The OBI grant will be used to review prior research studies examining the effects of physical activity on individuals with AD. Experts on AD will then come together with physical activity experts to discuss the findings, agree on a consensus statement, and produce the first draft of a tool kit that can be used by health care professionals, caregivers and other community members to plan safe and effective exercise programs for this population.

"Can we show that exercise helps alleviate depression in people with AD? Can it help improve mobility and activities of daily living? These are the kinds of things we will address," says Martin Ginis.

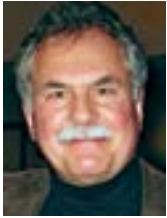
Getting knowledge out to the wider community where it can be used to implement programs and interventions that improve patient outcomes – that's the rewarding part, says Martin Ginis.

"People are used to going to the Internet for information, but the stuff that's out there is terrible. And it doesn't address risk factors and nuances that can affect specific populations."

SCI, MS and AD "are just the beginning," she says. "We have developed a proven systematic process that can be applied to any population to help plan exercise programs unique to their abilities and challenges. That's what makes it so exciting." ■

# IQ research matters

## GARY HASEY Machine learning improves psychiatric diagnosis



Gary Hasey

**When it comes to** diagnosing and treating mental illness, seeing is not always believing. Researchers at McMaster are finding that an individual's brain wave pattern

may actually be a better predictor.

For years, psychiatrists have been forced to make subjective decisions based on their observation of a patient's symptoms. The problem, says psychiatrist Gary Hasey, is that patients are not all alike.

"Historically, our decision making has been driven by the average person. But the average response rate to an anti-depressant is only 35%, which means two thirds of all patients are leaving the doctor's office with a prescription that's probably not going to work," says the associate professor in McMaster's Department of Psychiatry and Behavioural Neurosciences and director of the Transcranial Magnetic Stimulation lab at St. Joseph's Healthcare Mood Disorders Clinic in Hamilton.

Collaborating with researchers in the Departments of Electrical and Computer Engineering and the School of Biomedical Engineering, Hasey has found a way to take the guesswork out of decision making and improve the treatment odds by an astounding two-and-a-half to one. He does it by recording brain wave patterns with electroencephalography (EEG) and applying machine learning methodologies to predict outcomes.

Machine learning is a form of artificial intelligence in which a computer is "trained" to sort through vast numbers of variables and pick out the ones that are most important. It impacts our daily lives in many ways – our computer's ability to distinguish between spam and non-spam messages is one example of machine learning algorithms at work.

"What we are doing is training the computer to take thousands of variables and whittle them down to a few dozen that are highly correlated with treatment outcome," says Hasey. "Then, to end up with a smaller and more workable group, we get rid of those that are redundant.

"Consider height and shoe size – you don't need both because shoe size is a good predictor of height. Our algorithms are constructed to look at biological indicators in the same way. We end up with a small number of variables that together yield a very high discrimination rate that is extremely accurate."

Machine learning is a form of artificial intelligence in which a computer is "trained" to sort through vast numbers of variables and pick out the ones that are most important.

Machine learning to improve psychiatric diagnoses and outcomes is "brand new", says Hasey. McMaster is one of the few places using it. And it's paying off.

One set of algorithms discriminated, with 85% accuracy, those individuals in a group who were suffering from depression, bipolar disorder, schizophrenia or no mental illness at all. Another was able to identify, with an 89% success rate, whether or not a schizophrenia patient would respond to clozapine, a powerful but potentially dangerous anti-psychotic drug.

"This is a drug that can have very serious side effects. You don't want to be on it unless you have to be," says Hasey.

Other drugs, including the anti-depressant sertraline, an SSRI (selective serotonin reuptake inhibitor), have been tested with similar predictive accuracy.

The benefits to patients can be huge, says Hasey. "It takes at least six weeks to know whether an anti-depressant drug is working. If the first, second and third drug doesn't work, it can be nearly six months before the patient receives the right treatment."

It can also save money. More than two million Canadian adults take anti-depressants. Getting the correct diagnosis and drug out of the gate can shave more than \$12,000 off the cost of getting one patient well, a saving of \$24 billion annually. "The economic argument is very compelling," he admits.

Algorithms are now in place to test four additional drugs, as well as non-drug treatments, such as cognitive behavioral therapy (CBT). "We are building a catalogue drug by drug and treatment by treatment."

The researchers are also working to improve their algorithms by adding other kinds of measures – personality attributes, demographic characteristics, thyroid and vitamin levels – that may be directly or indirectly involved.

To move the technology forward from the lab to the clinic, the McMaster group has formed a company – Digital Medical Experts – and is in discussion with public and private investors, including the Ontario Brain Institute and insurance providers.

"We hope to eventually have a system whereby a physician or physician's assistant could place a portable brain wave set on a patient's head that would allow them collect and upload data and receive within minutes a diagnostic assessment and treatment plan specific to that patient. It's the ultimate in customized patient care." ■

# IQ research matters

## LAUREL TRAINOR Music “soothes the savage breast”



Laurel Trainor

### Why does a toddler

instinctively rock from side to side upon hearing music? Why do we tap our feet when we hear a favorite song? Why do we go to concerts

when we can listen to music at home?

Music impacts our mind and our body in ways that we are only just beginning to understand. It really does “soothe the savage breast”, lowering blood pressure, reducing anxiety, helping us feel connected, even easing pain.

Music psychologist Laurel Trainor is known for her groundbreaking neuroscience research on musical development in children and infants. In a 2012 study, funded by the Grammy Foundation, she found that musical training benefits children even before they can walk or talk – one-year-olds who participated in interactive music classes with their parents smiled more, communicated better and showed larger and earlier brain responses to musical tones.

The founding director of the McMaster Institute for Music and the Mind is now poised to extend our knowledge further with the establishment of an \$8 million performance lab that will monitor in real time what happens in the brains of musicians and audiences as they interact with each other.

“Until now, my research has focused on individuals. Yet one of the most important things about music is that it’s a social activity. We do it at parties, weddings, funerals, anywhere people come together to feel a common goal,” says the professor of Psychology, Neuroscience & Behaviour.

They are also more likely to help each other, Trainor’s research has shown. “We studied 14-month-olds and found that those who participated in simultaneous

movement to music with an experimenter were twice as likely to help that experimenter when she ‘accidentally’ dropped a crayon compared to infants who experienced out-of-synch movement with the experimenter. It made me realize that we need to study groups of people.”

The McMaster LIVE (Large Interactive Virtual Environment) Lab was funded with grants from the Canada Foundation for Innovation and the Ontario Ministry of Research and Innovation. Slated to open next year, it will look like an ordinary 100-seat concert hall, but many of its seats will be wired to measure

McMaster’s new LIVE Lab will provide researchers with rich sets of data that are not available anywhere else in the world.

audience members’ physiological responses – everything from brain activity and heart rate to breathing and perspiration.

Infrared motion sensors will record head movements. “We want to know if one person starts moving his head, do others start doing it as well?” says Trainor. “Do they feel affiliation with other members of the audience?”

Audience members are not the only ones who will be monitored. EEG recordings will reveal how musicians interact when engaged in the complex task of making music together.

“It’s not an easy thing at all. There’s an ongoing negotiation between musicians. Playing together requires the brain to

make models to predict what other musicians are going to do, because if you wait to hear what they do it’s too late to play in synch with them.”

The LIVE Lab will include a video wall to measure the cognitive and emotional impacts of media presentations and virtual acoustics capable of mimicking any space, from the very small to Carnegie Hall, to see how individuals are affected by different auditory environments.

The research applications are limitless, says Trainor, from improved hearing aids to new therapies for autism. “Everyone thinks music is fun but that it doesn’t really do anything important. But studying how the brain processes music can tell us a lot about how the motor system and the auditory system interact in general.”

Trainor’s group has shown, for instance, that if they present individuals with a rhythmic pattern of evenly spaced beats, and then slow down the tempo, the brain adjusts. “Recording EEG and MEG, we were able to analyze the oscillatory activity in the brain. We found that beta oscillations decreased after every beat and increased prior to the next. The brain was predicting the next beat.”

Even more interesting, she notes, is where in the brain that mental activity is occurring. “We saw activity in auditory areas, which was not surprising, but we also found it occurring in motor areas, which tells us that the two areas are in synch. They’re talking to each other.”

Trainor predicts that the knowledge gained from experiments in the LIVE Lab will be transformative. “There are other virtual labs out there but they’re not equipped to study both musician variables and audience variables. This facility will provide us with rich sets of data not available anywhere else in the world.” ■

# IQ feature story — Mike Noseworthy



■ Mike Noseworthy at McMaster's Imaging Research Centre. McMaster is home to the only Canadian imaging research lab equipped with MRI-compatible exercise bikes for the study of both adults and children.

**Engineering and the brain** may seem poles apart, but some of the most advanced technologies revealing the workings and structure of the human brain are being developed by engineers.

McMaster's Mike Noseworthy is one of those redefining how we see the brain, literally. An MRI physicist turned biomedical engineer, Mike heads the Imaging Research Centre at McMaster's Brain-Body Institute, where researchers are working to advance our understanding of how the mind, brain and body work together to influence health and disease.

Armed with one of the most sophisticated MRI scanners available, Noseworthy and his nine PhD students are pushing the limits of brain imaging in ways we've never seen before. They're writing new software and building hardware, mapping out new algorithms,

and building prototypes for everything from ergometric bikes that monitor how exercise affects the brain to sensor-equipped helmets that will alert hockey players to traumatic brain injury (TBI) at its earliest stages.

"We build stuff," says the associate professor, electrical and computer engineering. "Our students are trained not only in biomedical engineering, but also in anatomy, physiology and electrical and computer engineering. That's what makes the McMaster biomedical engineering program so fantastic."

Noseworthy's own CV reveals a storied past. He got into imaging as a graduate student in the mid-1980s, when MRIs were still in their infancy. Jobs were scarce then, and he ended up working as a pig farmer before landing a position imaging animals for the Ontario Veterinary College at the University of Guelph.

"You had to be a physicist to run the equipment back then. I did everything. I was building stuff, fixing stuff, doing research imaging on lab animals and clinical imaging of people's pets. Every day was a new challenge, and there was no one you could call for advice – I think there were only three human MRI scanners in Canada at the time."

He did his post-doctoral fellowship in imaging physics at the University of Toronto, then spent three years as a medical physicist at the Hospital for Sick Children, where he cut his clinical teeth and built his skills in neurosurgical planning. "My job was to map out key areas of the brain so neurosurgeons could choose the best surgical approaches."

When the offer came to head up McMaster's new Imaging Research Centre, Noseworthy jumped at the chance. "How

# Engineering and the brain

could I refuse an opportunity to run my own imaging lab with an MRI dedicated 24/7 to research? I was used to doing my research at midnight on clinical scanners that were unavailable during the day, so this was heaven.”

He arrived with his graduate and post-doctoral students in tow to a setup that was less than ideal. “It was just a big open area with a magnet in it. I sat in a carrel like a student, with piles of computers and books all around, running different software programs. We had 18 or 19 computers and it would get so hot in there that the students would strip down to their undies,” he laughs, quickly adding that back then it was an all-male group.

“I remember thinking: how do we grow this? I knew that non-invasive imaging technology was the way to go. I knew we had to build that.”

And build it he did, with funding from the Natural Sciences and Engineering Research Council (NSERC), the Canada Foundation for Innovation (CFI) and the Canadian Institutes of Health Research (CIHR), plus a \$2.5 million lab upgrade from St. Joseph’s Healthcare Hamilton where the lab is located.

The lab’s original MRI scanner has since been upgraded to a high-powered model that is twice the strength of a clinical model. It’s one of only a handful in the country earmarked solely for research, and the only one equipped with both broadband radio frequency and a proton decoupler.

The MRI scanner shares space with the region’s only PET/CT (positron emission tomography/computed tomography) scanner, an electroencephalography (EEG) system that can operate simultaneously with MRI, plus ultrasound and real-time optical imaging. There are also labs for building, testing and repairing custom magnetic resonance (MR) imaging coils and developing customized imaging phantoms that allow for fine-tuning various imaging devices.

But the equipment, while instrumental, is merely an agent for what Noseworthy and his research team do best – refine

McMaster’s Mike Noseworthy is one of those redefining how we see the brain, literally. An MRI physicist turned biomedical engineer, Mike heads the Imaging Research Centre at McMaster’s Brain-Body Institute, where researchers are working to advance our understanding of how the mind, brain and body work together to influence health and disease.

and combine the latest neuroimaging techniques to produce high-resolution brain maps and images showing structural, functional and metabolic abnormalities at their earliest stage.

Using a variety of advanced imaging methodologies – susceptibility-weighted imaging (SWI), diffusion tensor imaging (DTI), blood-oxygen-level dependent (BOLD) fractal dimension mapping – Noseworthy and his students are able to highlight specific areas of the brain that are improperly functioning or damaged, visualizations that would not be picked up by a conventional MRI scan.

SWI, for instance, produces high-resolution images sensitive to blood and iron, so micro-hemorrhages common to mild traumatic brain injury (mTBI) are easier to detect. Concussions and other forms of mTBI account for about 75% of TBIs, and can cause severe and longlasting effects. Yet fewer than one per cent of these injuries show up on routine MRI and CT scans.

“I saw a teenager who suffered a head injury, and a year and a half later he was still not right,” says Noseworthy. “He had gone from being an A student to a D

student, but his MRI scans were normal. Only when we used SWI were we able to detect the tiny previous hemorrhage spots.”

SWI is also being used to detect microbleeds linked to acute stroke and dementia, and is proving useful in quantifying iron content for multiple sclerosis (MS) and Parkinson’s disease. In a similar fashion, BOLD fractal dimension mapping helps to zero in on Alzheimer’s disease, which is linked to a reduction in (healthy) chaotic brain activity, while DTI captures subtle white matter abnormalities seen in mTBI and a host of other neurodegenerative diseases, including epilepsy and schizophrenia.

“Being able to find abnormalities in a person’s brain when routine clinical scans show the brain as normal really hits home with people who have had a brain injury,” says Noseworthy. “They know there’s something wrong, but the doctors say there isn’t.”

The Centre is also the only Canadian imaging research lab equipped with MRI-compatible exercise bikes for the study of both adults and children. Unlike routine MRI scans where subjects are told to keep still, patients are asked to put pedal to the metal to show good solid movement.

“It is well known that patients recovering from TBI often experience a recurrence of TBI symptoms with the onset of exercise,” says Noseworthy. “By measuring what is happening in the brain before, during and after exercise, we can more carefully monitor a patient’s recovery.”

He believes the potential to improve diagnosis, management and surgical precision is limitless. “Non-invasive neuroimaging is moving ahead by leaps and bounds. And because it’s only magnets and radiowaves, it can be used over and over again with no risk to the patient.

“The future will bring even better approaches with higher sensitivity that will improve our ability to diagnose and manage a whole range of diseases that we still don’t have an answer for.” ■

# IQ faculty feature

## KATHY MURPHY Better therapies for visual diseases



■ Kathy Murphy

**Imagine your brain as a ball of Play-Doh,** a malleable entity capable of constantly reshaping itself as it comes in contact with outside influences. It's called neuroplasticity, and it describes how neural pathways in the brain reorganize themselves in response to new experiences or sensory stimulation.

Kathy Murphy is a visual neuroscientist who is examining some of the most fundamental questions about how the brain develops and learns to see. By gaining new insights into how experience shapes the visual areas of the brain, she hopes to harness the brain's unique ability to reinvent itself into the development of new therapies for visual diseases.

Visual experience is one driver of neuroplasticity. It explains why children with amblyopia, more commonly referred to as lazy eye syndrome, are typically treated by patching their good eye,

forcing their weaker eye to work harder, thereby improving its vision.

Murphy's Visual Neuroscience lab uses a range of techniques, including measuring how we see, changes in synapses and neuroinformatics, to understand how visual experience impacts brain structure and function across the lifespan.

One myth she is intent on busting is our notion that the first three years of life are the only time to treat developmental brain disorders, rendering treatments for lazy eye syndrome and other early childhood disorders ineffective beyond a certain age.

"The truth is our brains are still developing at 20 and 30 years of age," says the professor in McMaster's Department of Psychology, Neuroscience and Behaviour. "This means that adolescent and young adult brains still have a lot of plasticity in them, and we can develop experience-driven activities that will promote the brain to rewire itself to function normally."

Murphy is uncovering the neurobiological mechanisms that show what is happening in the brain, then measuring them in a precise way in the lab using postmortem human brains and animal models. Her work is yielding insights that are leading to better therapies for amblyopia, congenital cataracts and other visual diseases.

"Lazy eye is one of the most common neurodevelopmental disorders in children, but we are finding that patching therapy is not always effective, especially with older children and young adults," she notes. "Our visual system is meant to have two eyes feeding into it, so binocular therapies may work better. This is a new concept for ophthalmologists, which could lead to a toolbox of therapies, rather than a one-size-fits-all approach."

Murphy is also studying age-related macular degeneration (AMD), a disease of the central retina that is the most common form of blindness in people over 50 in the developed world. There is currently no treatment, and it is slow to detect.

"A normal eye test doesn't work, because people with AMD can still score reasonably well even though the disease is progressing. They just kind of plod along until some critical point when they fall off the cliff."

She is currently collaborating with a pharmaceutical company and a local start-up on a more effective test for AMD. "We're developing a test that's sensitive to the early stages of the disease and that will allow us to try out different therapies and see if they work. We've already run one study with promising results."

An interesting byproduct of her work with animal models is the discovery that sexual maturation is not the best milestone to align brain age among species. "Human brains mature at a different pace than rodents, and we are slower to develop sexually. One of my students developed a method to measure synaptic age and it turns out the brain age of an adult rodent is equivalent to that of an eight- to 10-year-old child. This is crucial because it's really important for translating therapies to line up the right rodent model."

Murphy believes the future for neuroplasticity therapies is almost limitless, not only for healthy aging, but in the development of new and better treatments for a wide range of neurological conditions, psychiatric illnesses, and neurodevelopmental disorders, including autism. "If we can pinpoint what's causing these problems in the brain, then we can develop an adaptive plasticity process to rewire the brain to function normally." ■



# IQ research matters

## McMaster hosts inaugural Ontario Brain Innovation Council workshop

**What do the** San Francisco Bay Area and the Greater Boston Area have in common? They both capitalize on the geographic concentration of neurotechnology companies, access to capital, hospitals, universities and research institutes to create a vibrant neuroscience cluster. As with other industries, clusters allow their respective communities to reap the rewards of robust economic growth and job creation. Given that Ontario already possesses many of these assets and has an established world-leading role in neuroscience discovery, the question remains: will Ontario emerge as neuroscience cluster?

To answer this question, the Ontario Brain Institute (OBI) helped to assemble a group of participants from across Ontario, including partner organizations in OBI initiatives, academic

and treatment centres, funding and governmental agencies, and small or large companies to form the Ontario Brain Innovation Council (OBIC). This pan-Ontario council is mandated to develop, evaluate and support the growth of a neuroscience cluster and is already building new relationships, recruiting and developing talent and identifying new opportunities for organizations to work together.

In June of 2013 the inaugural OBIC Plenary session was held at the McMaster Innovation Park, drawing over 100 participants to discuss two important issues necessary for the emergence of a neuroscience cluster: 1) what assets and capabilities currently exist for the development of small-medium enterprises in Ontario, and 2) which metrics are most useful to evaluate the success and growth of the neuroscience cluster. Importantly,

this type of open discussion generates feedback directly from the various groups and individuals actively engaged in the commercialization of Ontario neuroscience research, and will help shape the development of the cluster in these early stages.

Among the attendees were Kathy Murphy, director of the McMaster Integrative Neuroscience Discovery & Study (MiNDS) Program, who serves as an OBIC Implementation Committee Member, and Michael Chrostowski, a MiNDS graduate and recipient of a 2012 inaugural, jointly-sponsored OBI and Ontario Centres of Excellence Entrepreneurship award.

As the emerging neuroscience cluster continues to grow, this first of many biannual meetings will be viewed as important milestone in the advancement of Ontario neuroscience and commercialization. ■



## Growing our community

**Great research builds strong communities.** It's a powerful resource that drives economic growth and social well-being. It's a vital engine that stimulates prosperity on the local, national and international levels. McMaster researchers are fully engaged with business, industry and government in addressing the challenges we all face living and working in a global environment. They are connected to their communities – providing solutions and mentoring the next generation of leaders. Their ideas, knowledge and discoveries will continue to fuel Canada's long-term economic health and development. Visit: [research.mcmaster.ca](http://research.mcmaster.ca)



# IQ faculty feature

## JOHN CONNOLLY Diagnosing disorders of consciousness



■ John Connolly won a Synergy Award at the University's Innovation Showcase 2013, for his multidisciplinary work on brain injury research.

**Imagine yourself in a hospital bed.** You see people around you, you can hear them talking, but you are unable to move or speak. The doctor tells your family that you are brain dead, and there is nothing that can be done for you. You will remain in a vegetative state (VS), for months or maybe years until your organs shut down and you eventually die.

This may seem like a scene from a science fiction movie, but it's not. Research suggests that, when it comes to diagnosing disorders of consciousness, what we see can be a very poor indicator of what is actually going on.

"If someone is not communicating it does not necessarily mean that all cognitive function has ceased," says John Connolly, a McMaster professor of linguistics and language. "We need to see what is going on in the brain, and we now have new ways of recording brain activity that we didn't have before."

His research into language, memory and the brain is changing how doctors

diagnose and treat people with acquired brain injury, non-verbal autism and disorders of consciousness, including VS, minimally conscious state(s) and coma.

If you're wondering how a "language guy" who studies phonology, orthography, and semantics got involved in neuroscience, Connolly says the answer is simple. "Language is fundamental. It's also the route we can take to access somebody's mental life."

The Senator William McMaster Chair in Cognitive Neuroscience of Language used electroencephalography (EEG) to measure brain activity in a 20-year-old man who had been diagnosed VS after being stabbed in the head. Using a simple sentence comprehension task to test cognition, the EEG showed activity in that part of the brain responsible for semantic processing.

"It was clear that he was doing some very sophisticated language work inside his head," says Connolly. "His brain just couldn't control his motor system."

On the strength of Connolly's tests, the patient went on to receive standard rehabilitation treatment he would otherwise have been denied. Although he never spoke again, he was able to leave hospital and eventually return to work.

Another patient, a 46-year-old cyclist hit by a car, came out of his coma four months later only to be diagnosed VS. He showed normal semantic responses when tested with EEG while engaged in a word/picture association task. "His first words were actually a song. People were singing 'Happy Birthday' to another person on the ward, and he joined in." The man has regained full speech and is now in the process of learning to walk.

Connolly has patented his computer presentation of psychometric assessment tests and simultaneous brain activity measurement (now called NeuroVox®), and has been awarded a Natural Sciences

and Engineering Research Council of Canada Engage Grant to pursue additional commercial opportunities with an Ottawa-based company, Personal Neuro Devices.

He has developed similar tools to assess cognitive functioning in other populations who also suffer from an inability to communicate with the outside world. Autism Speaks and the Ontario Brain Institute have both funded his research on children with non-verbal autism. Because these children are typically labeled low-functioning, therapeutic interventions are often withheld.

"We are now analyzing the first wave of these children. They are not large numbers, but we found two children whose brain activity does not fit the expectation of low-functioning," says Connolly.

His research is now being expanded to include the study of coma and concussion. He notes that some people emerging from coma have memories of events that actually took place around them while they were in coma. "By introducing speech intervention therapies in coma, we may strengthen their ability to communicate when they come out of coma. Nobody has ever done this."

The problem with concussions, he says, is that without an early diagnosis a serious injury may go untreated. "We think we can develop a scaled-down version of NeuroVox® that can be used to provide very fast assessments right on the sidelines that can be used to determine when a player should be pulled and when they can safely return to play."

The same techniques, he believes, hold promise for other non-communicative populations, from stroke and dementia sufferers to ICU and anesthesia patients.

Says Connolly: "When every form of communication is failing you, you have to let your brain do the talking." ■

# IQ faculty feature

## KARIN HUMPHREYS Turning thoughts into words



■ Karin Humphreys (right) pictured with her colleague Alex Sevigny, associate professor in the department of communications studies and multimedia.

**How many times** have we heard the phrase, “we learn from our mistakes”? While it might be true for life lessons, when it comes to errors in language, research shows we may actually be learning to make the same mistake over and over again.

“We all think that practice makes perfect, and speaking is also practicing,” says Karin Humphreys, a psycholinguist who specializes in errors in language. “But if we’re in a tip-of-the-tongue state and working hard to think of a word, we may be reinforcing a pattern of error. It seems that whatever we practice is what we learn.”

The associate professor of psychology, neuroscience and behavior at McMaster says having a word on the tip of your tongue, a word you know you know but just can’t retrieve from your mind, is very common – and frustrating.

“Turning thoughts into words may seem like second nature to us, but it takes a huge amount of work. When we speak, we don’t do it word by word. Our brain is always planning ahead, forming the structure of the sentence, its meaning, the grammar and

sounds before we even open our mouths.”

Finding the right word, she says, requires us to plan for the future and stop doing what we’ve done in the past. When that system gets blocked, we become annoyed and distressed, and the tendency is to work even harder to retrieve the word in the belief that we will prevent ourselves from making the same mistake again.

Humphreys’ research, funded by the Natural Sciences and Engineering Research Council, shows this approach may be doing more damage than good.

She tested people by giving them definitions for words not used in normal conversation (“filibuster” was one). They were randomly assigned time limits – either short or long – to come up with the word. If they couldn’t retrieve the word in the time allotted, they were given the answer and asked to confirm whether it was the word they were trying to think of.

When the subjects were tested 48 hours later with the same definitions, almost half them were still unable to retrieve the words, despite having been told them and

agreeing they knew them just two days before. And the longer they were given to think about it, the more likely they were to forget the second time around.

“It appears that getting it wrong once makes us learn the wrong pathway, and we are more likely to make the same mistake again,” says Humphreys.

She’s found a way to improve the odds, though, by providing a clue to those who are struggling to come up with the word. “When we gave them the first couple of letters, the rate of success the second time around jumped to 85%.

“We’re now experimenting to find out which clues help the most. Is it the beginning sound, or another whole word that sounds the same, or something else? It may be that there’s a sweet spot for the amount of work you need to do yourself to have success.”

Humphreys’ research could have important implications for everything from second-language learning to the development of therapeutic protocols for brain injured patients. “People who have suffered a concussion often have difficulty remembering words. Therapy typically involves lots of practice in word naming, but this approach may be dooming them to failure.”

Humphreys recently received a Forward with Integrity grant to study TOT state in the elderly. “We’ll be taking the lab into the community, partnering with area retirement homes to look at how language processes can be optimized for healthy aging.” Forward with Integrity is a McMaster initiative that provides seed funding for projects that build collaborations with the wider community.

“Our goal is not just to do the science. We want to get our students out of the university and interacting with older adults to create a longer-term community partnership.” ■

# IQ faculty feature

## SCOTT WATTER Do brain exercises improve cognition?



Scott Watter

**Is it possible** to retrain your brain? Aging baby boomers are banking on it, doing crossword puzzles, playing Sudoku and watching Jeopardy in an attempt to sharpen their brains

and ward off memory loss and dementia.

The problem is that there has been limited scientific evidence to support the theory that engaging in brain exercises improves cognition in general.

New findings replicated in four major, long-term studies conducted at McMaster could change that. Scott Watter, an associate professor in the Department of Psychology, Neuroscience and Behaviour, found that people who played video games incorporating memory puzzles and visual perception tasks performed better in standard cognitive tasks after just 10 hours of gameplay.

“We all know that practice makes for better performance, but only when it comes to the specific task being performed. For example, people who practise riding a bike get better at bike riding,” says Watter, who specializes in the study of how our brains organize, control and coordinate themselves to perform complex tasks.

“What this study tells us is that improved performance in one task can be transferred to other tasks requiring the same cognitive process.”

Armed with a Natural Sciences and Engineering Research Council Engage Grant, Watter teamed up with Telos Entertainment Inc., a leading Canadian video game developer, to design a video game that would incorporate cognitive training aspects while still being fun to play.

They were careful to choose only novice gamers to participate. “The literature already shows that people who are experts at video gaming have better

cognitive and perceptual skills. But we don’t know whether the gaming made them better, or they are better gamers because they are already highly skilled in these areas. We had to be sure we were testing whether the games themselves improved cognitive skills.”

To determine their existing level of ability in attention and perception, the subjects were pre-tested on a variety of tasks, things like finding the “b” in a page of letters and picking out a left- or right-pointing arrows on a page crowded with other symbols. “We wanted to know how quickly they could find things, and how well they could ignore distracters,” says Watter.

people who played video games incorporating memory puzzles and visual perception tasks performed better in standard cognitive tasks after just 10 hours of gameplay.

The video game incorporated features designed to engage gamers in these same careful discrimination and selective attention skills. They had to manipulate a 3-D object and remember where different pictures were located. They had to shoot paint balls at bandits but not splatter paint on the sheriffs, who looked very similar – “a very high-interference distracter involving a lot of perceptual effort,” says Watter.

In a test of their long-term memory skills, gamers were forced to battle through wizard fortresses, remembering arbitrary pairs of items seen along the way as their only means of escape.

A key programming feature was the ability to adjust the level of difficulty inside the game based on how well a participant was doing. If someone did well on a task, the game would automatically speed up, ensuring it remained challenging and rewarding for everybody.

Participants were required to play the video game for 40-50 minutes each day for two weeks, at which point they were re-tested using the same pre-test they had completed at the start.

The results, says Watter, surprised even him. “We did see improvement on the specific perceptual tasks as a result of the game training. But what was particularly unexpected was that we also saw an enhancement in our gamers’ ability to extract information and store it in long-term memory. It appeared we may have been training up some fundamental cognitive abilities.”

Still skeptical, Watter’s team repeated the study three times with similar results. Their findings were presented in November at the Annual Meeting of the Psychonomic Society.

Watter is excited by the results. “It demonstrates that there’s still this high degree of trainability. Will playing high-attention video games make our brains healthier? Could it help us to remember where we left our keys? Potentially, yes.”

He says the research is also exciting for what it says about how the brain works. “It tells us that we can cope with a lot of what goes on around us. We do it by processing what’s important and tuning out what isn’t it.

“We have a constant barrage of sounds and sights and smells, yet we have this amazing ability to select and make sense of it all. As good as we are at this, it’s important to know that we can keep improving with the right kinds of practice.” ■

# IQ faculty feature

## HUBERT de BRUIN Innovative helmet measures impact on the brain



Hubert de Bruin

**Recent headlines** have put sport-related concussions under the microscope. But settlements like the multi-million dollar payout to former National Football

League players, while reducing the burden of care for families, do nothing to protect players from incurring such injuries in the first place.

Researchers led by Hubert de Bruin, an associate professor in McMaster's Department of Electrical and Biomedical Engineering, are close to unveiling something that will – a hockey helmet that can measure the force and direction of a blow as it happens and the brain's immediate response, alerting players and coaches to the possibility of neural injury before they even leave the ice.

It promises an important breakthrough in a sport where impacts to the head can account for up to 24% of all injuries. And they don't have to be major hits. It is now known that many small sub-concussive hits sustained over a long period of time can be just as devastating, leading to lifelong cognitive and/or functional deficits.

McMaster's prototype, two years in the making, is not the first helmet to measure blunt force to the head. Helmets equipped with accelerometers, which use algorithms to calculate helmet and head acceleration, have been recently developed and sold.

"The problem is that these measure the force on the helmet, but they don't measure the impact on the brain," says de Bruin. The McMaster team, which includes fourth-year undergraduate students, has refined this first-generation model, installing pasteless electrodes to provide continuous monitoring of a player's brain activity, as well as all electronics and the battery, inside the

helmet. The information is continuously transmitted to the bench using wireless Bluetooth technology.

"We had smaller circuit boards made in China, and we came up with a lighter battery," says de Bruin. "The whole thing weighs only about 150 grams and we've managed to get the cost down so that it adds only slightly to a player's total equipment cost. It should be something that every little leaguer can afford."

The most exciting part is what happens next, says de Bruin. Using a simple laptop computer programmed to administer a modified electroencephalogram (EEG), players who have been hit hard will receive an immediate, automatic EEG analysis to see exactly what is happening in their brains. If abnormalities are detected, players can be advised to have a full EEG or brain scan. "In effect, the helmet system functions as a triage device."

De Bruin says the potential to reduce and manage sport-related concussions is huge. "We now have a working model and are looking to the electronic industry to aid in the development and manufacture of multiple units."

De Bruin is no newcomer to the commercialization of neurotechnology. In a career spanning more than three decades, his contributions to neuroelectronics and bioinstrumentation have been varied and novel.

He was among the first rehabilitation professionals in the province to assess muscle response in acquired brain injury patients. Working with the Prosthetics and Orthotics Department of Chedoke Hospital (now part of Hamilton Health Sciences), he designed a prosthetic leg for amputee runner and cancer research activist Terry Fox – the first developed specifically to absorb the shock of running. Fox died before he had a chance to try it out, and the leg now

stands like a silent sentinel in the corner of de Bruin's office.

As coordinator of the Bachelor and Masters programs in electrical and biomedical engineering, de Bruin is inspiring a new generation of students to make their mark in this fast growing field.

"It's a very exciting time," says de Bruin. "We have powerful technologies available to us that didn't exist before to improve diagnosis and develop better therapies." ■

### Among their innovative inventions:



■ **The CPR Glove**, a neoprene glove embedded with sensors to guide first aiders in CPR. It was named one of the top inventions of 2007 by TIME and Popular Science, and kick-started a spin-off company, Atreo Medical, ultimately bought by Medtronic, the world's largest medical technology company. Above photo from left: two of the three McMaster University inventors Nilesch Patel and Corey Centen (absent from photo is Sarah Smith).

■ **A device that speeds recovery** from nerve injury by electronically stimulating muscles. Developed in concert with a plastic surgeon and basic neuroscientist, it has attracted support from Med-El, a world leader in artificial ear implants.

■ **A brain-computer interface** that allows an individual to control a wheelchair just by thinking about it.

# IQ other news

## SIGNED & SEALED: McMaster and Fraunhofer formalize partnership

**McMaster University has signed** a Memorandum of Agreement with Fraunhofer IZI (Leipzig, Germany), marking the next phase in their collaborative research partnership.

A delegation of senior executives and scientists from Fraunhofer IZI visited McMaster in September for research presentations, a tour of McMaster's world-renowned research centres and to participate in the formal signing ceremony.

McMaster's vice-president of research and international affairs, Mo Elbestawi, acknowledged the visit and the signing as a critical step in the long-term plan to create a Fraunhofer Project Centre, headquartered in Hamilton. Ideally, he says, the Centre will be a "catalyst in further developing the region's bioeconomy."

The next immediate step is to complete two pilot projects: The first will focus on the development of novel tools for cancer immunotherapy and is led by Professor Jonathan Bramson, director of the McMaster Immunology Research Centre and Christopher Oelkrug, head of the Fraunhofer IZI's Immunotherapy/Oncology group.

The second, led by McMaster assistant professor of engineering physics, Leyla Soleymani, will focus on reducing the cost of tuberculosis diagnosis and enabling a more effective treatment selection. She'll be collaborating with Dirk Kuhlmeier, head of the Nanotechnology unit at Fraunhofer IZI.

The most recent visit highlighted additional areas for research partnership opportunities between the two institutions, namely cognitive linguistics and biointerfaces research.

"This is just the beginning of a long-term partnership," says Elbestawi, who visited Fraunhofer IZI in November. "There are enormous opportunities to work together to develop a number of industry-relevant R&D projects and to lay the foundation for future investment from public and private partners in both jurisdictions."

Director of Fraunhofer IZI, Frank Emmrich, agrees the collaboration potential is significant. "Having visited McMaster twice, learning first-hand about their research capabilities and seeing some of their world-class facilities, we know this is an institute with which we have much in common and we are anxious to move this project along – a project that will bring economic benefits to both regions." ■



■ From left to right: Stephen Collins, associate dean of research in McMaster's Faculty of Health Sciences, Patrick Deane, McMaster's president & vice-chancellor, Frank Emmrich, director of the Fraunhofer IZI, and Mo Elbestawi, McMaster's vice-president of research & international affairs, are all smiles as they sign an agreement which will see the two institutions collaborate on a number of research projects.

# IQ other news

## Meet McMaster's newest Canada Research Chairs

The **Canada Research Chairs Program** was launched by the federal government in 2000 to help Canadian universities attract and retain the world's best researchers. McMaster University has been allocated 69 Canada Research Chairs, the third highest number of Chairs allocated in the province of Ontario and the ninth highest in Canada. We welcome our newest and our renewed chairholders:



**Mick Bhatia**, Canada Research Chair in Human Stem Cell Biology, Tier 1, is the Director and Senior Scientist at the Stem Cell and Cancer Research Institute.



**Catherine Connelly**, Canada Research Chair in Organizational Behaviour, Tier 2, is an associate professor of organizational behaviour and human resources management.



**Jonathan Draper**, Canada Research Chair in Human Stem Cell Lineage Commitment, Tier 2, is an assistant professor in the department of pathology and molecular medicine and a scientist at the Stem Cell and Cancer Research Institute.



**Michelle Kho**, Canada Research Chair in Critical Care Rehabilitation and Knowledge Translation, Tier 2, is an assistant professor in the School of Rehabilitation Science.



**Mark Larché**, Canada Research Chair in Allergy and Immune Intolerance, Tier 1, is a professor of medicine (clinical immunology and allergy/respirology).



**Nathan Magarvey**, Canada Research Chair in Natural Product Drug Discovery, Tier 2, is an assistant professor in the departments of biochemistry and biomedical sciences, and chemistry and chemical biology.



**Maureen Markle-Reid**, Canada Research Chair in Aging, Chronic Disease and Health Promotion Interventions, Tier 2, is an associate professor in the School of Nursing.



**Natalia Nikolova**, Canada Research Chair in High Frequency Electromagnetics, Tier 2, is a professor of electrical and computer engineering.

Learn more about McMaster's Canada Research Chairs at [research.mcmaster.ca](http://research.mcmaster.ca)



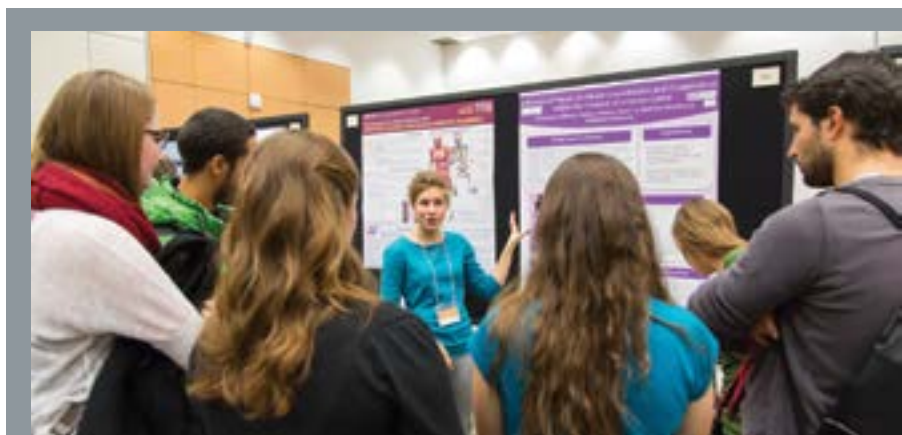
**Eva Szabo**, Canada Research Chair in Metabolism in Human Stem Cells and Cancer Development, Tier 2, is a principal investigator in the Stem Cell and Cancer Research Institute, and assistant professor in the departments of biochemistry and biomedical sciences, and medicine (endocrinology & metabolism).



**Gregory Steinberg**, Canada Research Chair in Metabolism and Obesity, Tier 2, is an associate professor in the department of medicine (endocrinology & metabolism).



**Shiping Zhu**, Canada Research Chair in Polymerization Engineering, Tier 1, is a professor and chair in the department of chemical engineering. ■



### UNDERGRADUATE STUDENT RESEARCH AWARDS POSTER SESSION

■ Stephanie Williams, from the department of psychology, neuroscience & behaviour, engages the crowd at the 2013 Undergraduate Student Research Awards Poster Session held in November. Her poster, *The Influence of Motor Coordination and Cooperaton within the Context of a Dance Game*, was one of 40 presented by students. Each year, some 100 undergraduates are awarded the prize to do supervised research for a 16-week period.

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