Christchurch Neurotechnology Research Programme
Annual Update – April 2006

1. Introduction

The Christchurch Neurotechnology Research Programme is based in the *Van der Veer Institute for Parkinson's and Brain Research* but represents a formal collaborative venture between the CDHB, the University of Otago (Christchurch School of Medicine & Health Sciences), the University of Canterbury, and the Van der Veer Institute. The key personnel are:

- Staff – Richard Jones (Director, CDHB & UO & UC), Paul Davidson (Deputy Director, CDHB), Carrie Innes (Postdoctoral Research Fellow, CDHB), and Roger Bellamy (Software Engineer, CDHB).
- Postgraduate students – Malik Peiris (PhD, ECE, UC), Daniel Myall (PhD, Medicine, UO), Amol Malla (ME, ECE, UC), and Govinda Poudel (PhD, Medicine, UO).
- Affiliated staff & Postdoctoral Fellows – Philip Bones (UC), Grant Carroll (CDHB), John Dalrymple-Alford (UC), Marcus Heitger (UO), Richard Green (UC), Michael MacAskill (UO), and Tim Anderson (UO).

The Programme is primarily funded by FRST and currently funded until June 2007 (including a one year extension approved last year). Further funding beyond that time will be sought from FRST later this year. The Programme and associated research projects also were successful in gaining funding during the past year from the Canterbury Medical Research Foundation, the Neurological Foundation, and Accident Compensation Corporation.

2. Outline of Research Activity

Research in the Programme falls largely within four primary areas with activity and achievements over the past year as follows:

Prediction of on-road driving ability from off-road tests

Carrie has submitted her PhD thesis on "Prediction of driving ability via computerized sensory-motor and cognitive tests in persons with brain disorders" and subsequently been awarded her PhD by the University of Otago. A great achievement. Carrie's research study focused on 50 persons with neurological disorders referred for driving assessment to the Driving and Vehicle Assessment Service (DAVAS at Burwood Hospital, plus 60 control subjects. Her research led to the development and commissioning of several novel driving-relate cognitive tests (including an NZ patent and PCT on the Visual Search test) to the standard off-road driving assessment and also led to the determination, validation, and implementation of automated procedures for optimal prediction of ability to drive safely without having to undertake a potential risky on-road assessment. Carrie presented papers on her research at *27th Annual International Conference of IEEE Engineering in Medicine and*

Biology Society (*EMBC 2005*, September 2005, Shanghai), the Canterbury Health Research Conference, and Workshop of Occupational Therapy Driving Special Interest Group in Nelson. We are also well advanced on publications arising from this research. A big boost to Carrie – and the Programme – was Carrie being awarded the prestigious Canterbury Medical Research Foundation Post-Doctoral Research Fellowship in August 2005, which has allowed her to continue her research in the Programme for a further 3 years. This will involve a second major study in the Driving Assessment Research Programme, focused on refinement and validation of procedures for driving prediction (as well as allowing Carrie to extend her research skills and interests into the lapse research area – see below).

Carrie's research has led to the evolution of two models of off-road driving assessment & prediction systems: (i) a high-end system, as at Burwood Hospital with cut-down car-body and interfaces and (ii) a less expensive semi-portable system – *CanDAT*™ (Canterbury Driving Assessment Tool) – which uses the same *SMCTests*™ (sensory-motor & cognitive tests) software but based around a laptop and a steering wheel & pedals unit from USA. Closely related to the two models are two assessment and prediction modalities: (a) a full-assessment version for use by specialist driving assessment therapists and (b) a screening version, with a much shorter assessment time, which will hopefully prove attractive to GPs, who all have a mandatory responsibility to assess and ratify driving abilities; the difficulty GPs are faced with in meeting these responsibilities will accentuated in November when the current requirement for older-age drivers to undertake an on-road assessment ceases.

Detection and characteristics of lapses of responsiveness

Several projects are under way looking at various aspects of lapses of responsiveness ('lapses'). There is growing evidence that such lapses can be due to microsleeps, when the brain turns off for a few seconds due to a brief shutdown in our arousal system, and to lapses on tasks requiring sustained attention, which can occur even when person is supposedly alert. Our Lapse Research Programme is looking at various aspects of lapses and drowsiness, specifically (i) detection and prediction from electrophysiological and video data, (ii) characteristics, such as rates, durations, changes over time, and differences between individuals, (iii) factors, such as age, gender, sleep deprivation, air temperature, and type of task, (iv) effectiveness of counter-measures, such as breaks, naps, coffee, music, lower temperatures, and (v) underlying mechanisms in the brain.

Malik is close to submitting his PhD on characteristics and EEG-based detection of lapses. In addition to papers at *EMBC* conferences, he is close to a major publication on lapse characteristics. Amol Malla is well advanced on his ME on the development of a computer-vision-based system for automated detection of drowsiness and lapses by measuring eye closure and eye movements from video images of a person's face. Carrie will be undertaking several studies aimed at determining the extent to which various factors affect the likelihood of lapsing and the effectiveness of various counter-measures to reduce the likelihood of lapsing.

Paul provides a critical input into all of these projects, in addition to his own research which is largely focused on the detection of lapses. Using recurrent neural networks, he has developed a system able to detect lapses from the EEG better than any other system reported in the literature. He presented a paper on this work at *EMBC 2005* and is close to a major publication. Paul is also forging a new direction for detection, based on the development of a head-mounted lapse detection device, which will look a bit like a telephonist's headset and incorporate a miniature video camera, an infra-red LED, an accelerometer, dry EEG electrodes, an auditory warning output, signal/image processing electronics, and a power supply. This is an exciting new approach but is still in the proof-of-concept stage. We took out two provisional patents last year to gain IP protection of the concept and of a novel method for training and validating lapse detection systems.

We have commenced a research project aimed at better understanding what happens in the brain during various types of lapses. The project aims to study lapses using simultaneous fMRI, EEG, video, and visuomotor performance during a continuous 2D tracking task. This is a very challenging project, involving 13 co-researchers, including 3 based overseas (Italy and USA) with special expertise in fMRI and/or EEG methodology. Govinda will be working full time on this project over the next 3 or so years as a new PhD student in Department of Medicine at the University of Otago, supervised by Richard and Paul. Govinda is from Nepal (as is Amol) but has spent the last few years at the University of Technology in Sydney where he gained a 1st Class Honours degree in Engineering.

Prediction of outcome following mild traumatic brain injury

Marcus was awarded his PhD last year and was also awarded a Post-Doctoral Fellowship from the University of Otago. He is continuing his excellent work in the area of subtle motor deficits following mild TBI in which he has been able to demonstrate sustained subclinical deficits in patients who were otherwise thought to have sustained no long-term adverse effects following mild head injury (e.g., concussion and subsequent visit to an Emergency Department). Importantly, not only are these deficits, including post-concussion syndrome, long-term in many cases, they can also be predicted more accurately than by other measures such as neuropsychological tests, allowing such patients to be identified for special treatment at, say, Burwood's Concussion Clinic. In addition to further publications and conference presentations over the past year, Marcus has been successful in gaining funding from the Neurological Foundation and from ACC for further research in this area. He also has funding from CMRF to allow him to use advanced MRI techniques to look for structural and functional changes in the brain of persons with mild TBI, but this study is on hold pending the commissioning of Christchurch Radiology Group's new GE 3T MRI scanner on the ground floor of the Institute later this year.

If a current major validation study on TBI outcome prediction proves successful, we will be looking very closely at possibilities for development and commercialisation of a portable laptop and video-camera based system for outcome prediction based upon oculomotor deficits.

Virtual-reality-based neuro-rehabilitation tools

Daniel has further enhanced the virtual-reality and 3D multi-sensor position measuring system in the Movement and Virtual Environment (MoVE) laboratory at the Institute. A major collaborative study with Michael MacAskill is about to commence which will help answer several key questions regarding arm-movement deficits in persons with Parkinson's disease and explore possibilities for improving arm function by using VR as a neuro-rehabilitation tool to re-tune deficient internal models in the brain of such patients. Daniel will also be using data from this study to validate an improved computational model of the brain he is developing to take better account of the dopaminergic deficiency in Parkinson's disease.

The MoVE Lab is also moving into the lower-limb domain. Capacity to measure ambulation within an immersive environment is being added by way of a helmet-mounted display, providing complete control of the visual information shown to subject, and a Polhemus *Long Ranger* to track limb segments during walking over a reasonable distance. Peter Steenbergen, on Biomedical Engineering Workshop Training from University of Twente (Enschede, The Netherlands), is working with Daniel and Michael on helping set up this system.

3. The long road to commercialisation

Commercialisation of one or more innovative products rising from the Programme remains an important long-term goal, but certainly not an easy one. Last November, Richard and Paul featured in a Sensor Showcases run by Connect Canterbury. In addition to presentations on *CanDAT* and lapse detectors, the Showcase was the occasion of the first public demonstration of *CanDAT*, which turned out to be a big attraction. Over the past few months, Paul, Carrie, Roger, and Richard have focused considerable energy on the development of *CanDAT*, particularly in relation to the *SMCTests* software, hardware interfaces, optimal groups of tests, deficit profiles, on-road prediction for full- and screening-assessment modalities, and documentation. It is now a polished product and ready for pre-release evaluation outside of the CDHB and subsequent commercialisation.

4. Other News

In August 2005, the Neurotech Team had a strong presence at *EMBC 2005* in Shanghai (a fascinating city). Richard co-chaired the *Neural Systems and Engineering* theme (third largest at conference), chaired tracks on 'Clinical Neurophysiology and Neuroengineering' and 'Human Performance – Normal function in neurological disorders', and chaired and organized Special Sessions on 'Early and differential diagnosis of neurological and neuropsychiatric disorders' and 'The wake-sleep continuum – behavioural and physiological'. Richard, Paul, and Malik presented papers in the latter, and Carrie presented a paper in the same track. As Co-Chair of the Neural theme, Richard ended up in extended interview by Japan Broadcasting Corporation for a documentary on "Cyborg developments and future directions in neural engineering", which appeared on National Japan Television last November. Presumably both he and the Japanese interviewer were subtitled in Japanese.

Bronwyn Kelly, supervised by Maggie-Lee Huckabee and Richard, is close to submitting her PhD thesis on "Cortical influence on the coordination of swallowing and respiration in adults" in the Department of Communication Disorders at University of Canterbury. In addition to several conference papers, Bronwyn submitted several papers on her research over the past year, one of which is in press in *Respiratory Physiology and Neurobiology*.

In addition to being a member of the Editorial Board of *Journal of Neural Engineering*, Richard was invited and appointed an Associate Editor of *IEEE Transactions on Neural Systems and Rehabilitation Engineering* earlier this year. He also had the 'pleasure' of being external examiner for two PhD theses in neural engineering submitted to University College Dublin and the University of New South Wales.

Richard Jones
3 April 2006