

Christchurch Neurotechnology Research Programme

April 2008 – March 2009

www.neurotech.org.nz

Richard Jones

Director

Introduction

The *Christchurch Neurotechnology Research Programme (NeuroTechNZ™ – ‘NeuroTech’)* is a joint venture between CDHB (Medical Physics & Bioengineering, Neurology), University of Otago, Christchurch (Medicine), and University of Canterbury (Electrical & Computer Engineering], Psychology). NeuroTech is physically based at the *Van der Veer Institute for Parkinson's and Brain Research*.

- **NeuroTech personnel**

Staff

- Associate Professor Richard Jones – Neuroengineer/scientist and Director of Programme, CDHB & UOC & UC & VdVI
- Dr Carrie Innes – Neuroscientist and Research Fellow, CDHB & VdVI

Students (+ degree sought)

- Daniel Myall – PhD, Medicine, UOC
- Govinda Poudel – PhD, Medicine, UOC
- Petra Hoggarth – PhD, Psychology, UC
- Amol Malla – ME (awarded 2008), Electrical & Computer Engineering, UC
- Russell Buckley – MA, Psychology, UC
- Jie Chen – BE, Electrical & Computer Engineering, UC

Affiliated staff & Research Fellows

- Professor Philip Bones – UC
- Associate Professor John Dalrymple-Alford – VdVI & UC
- Dr Michael MacAskill – VdVI & UOC
- Dr Marcus Heitger – VdVI & UOC
- Dr Richard Watts – VdVI & UC
- Professor Tim Anderson – VdVI & UOC & CDHB
- Associate Professor Deak Helton – UC
- Dr Leigh Signal – Massey U

- **Funding**

On the research funding side of things, 2008 was a distinctive and much-needed improvement over 2007. Of greatest importance was our success in last year's round of the prestigious and highly-competitive Marsden Fund for the 3-year project 'Losing the struggle to stay awake: What happens in the brain during a lapse of responsiveness?' (March 2009 – Feb 2012).

Also important was Carrie's being awarded a prestigious Postdoctoral Fellowship from Accident Compensation Corporation for the project 'Avoiding accidents due to lapses and errors in sleep-deprived people'.

We were also successful with smaller funding applications to Canterbury Medical Research Foundation for projects in the lapse and driving domains.

Research Activity

A. *Driving Assessment Research Programme*

Carrie, Petra, John, and Richard have four research studies in progress aimed at (1) validation and improvement of our Canterbury Driving Assessment Tool's (*CanDAT*TM) (Figure 1) ability to predict 'medical fitness to drive' and 'ability to drive safely' based primarily on performance on a battery of computerized tests of sensory-motor and cognitive function (*SMCTests*TM) and (2) improving our understanding of the complex task of driving and the medical and non-medical factors which can prevent a person from driving safely:

- Study 1 – Determination of the accuracy of prediction models in both the Full and Screening Assessment versions of *CanDAT* when applied to a population of 60 healthy older-aged persons. Petra (supervised by Richard, Carrie, and John) has completed the data collection of this study, as part of her PhD project in Psychology, while also undertaking her Postgraduate Diploma in Clinical Psychology. In addition to the *CanDAT* tests and a blinded on-road assessment, Petra assessed participants on a range of standard tests of cognition/dementia, anxiety, aggression, and mood. Surprisingly, 16 of the participants failed the on-road test. Petra has shown that 'non-causal resource analysis' modelling is able to classify/predict Passes and Fails substantially better than 'binary logistic regression'.
- Study 2 – Petra has completed the first year of a two-year follow-up of driving accidents



Figure 1. Carrie being tested by Petra on *CanDAT*.

and traffic violations in the healthy older drivers study. The aim is to determine, as much as one can, the extent to which performance on the on-road assessment correlates with the true gold standard for safe driving of accidents and violations. The latter information is obtained from the participants themselves and from Land Transport NZ and the Ministry of Transport. To our knowledge, this is the first study to have followed up on-road assessments in people for which there were no consequences from the assessment—i.e., persons who failed the on-road were permitted to keep driving. While the number of subjects, base rate for accidents/violations, and length of study will limit the conclusions we can draw from this study, the preliminary 1-year results have shown no evidence of a difference between the on-road Pass and Fail groups!

- Study 3 – Earlier this year, Petra commenced a new study focused on persons with mild cognitive impairment or early dementia referred for a driving assessment to Burwood Hospital's Driving and Vehicle Assessment Service. This study is looking at performance on *CanDAT* tests, several standard cognitive tests, and a blinded on-road assessment. These type of patients have previously proven particularly problematic as some have been found to perform poorly on *CanDAT* but still pass the on-road assessment.
- Study 4 – O'Leary Driving Assessment Services (Wellington and Palmerston North) and OTRS Group Ltd (Hamilton and Tauranga) are both progressing well towards their targets of 200 referrals each of persons with definite or suspected brain disorders. They are assessing these via independent off-road and on-road assessments.

Carrie has a paper in press in *Behavior Research Methods* on the performance of normal subjects on *SMCTests*. Over the past year, Petra presented talks on Study 1 at the *New Zealand Psychological Society conference* (at which she was awarded Best Student Conference Paper), University of Canterbury's *Postgraduate Research Showcase* (at which she was awarded the College of Science prize for best presentation), and *International Neuropsychological Society* conference in Atlanta. Carrie presented papers at *AWCBR'08* and *EPSM'08*. Carrie and Petra are heading off soon to *Driving Assessment 2009* in Montana with papers to present on aspects of their research.

- **Commercialisation**

Via a formal Agreement with CDHB, the *Canterbury Innovation Incubator* (www.cii.co.nz) is well underway with its pre-incubation investigation of *CanDAT*, including determination of the NZ and global need, alternative commercialisation possibilities, etc.

B. Lapse Research Programme

Several projects are under way looking at various aspects of complete lapses of responsiveness ('lapses'). These lapses can be anywhere from 1 to 15 s duration and are due to behavioural microsleeps, where the brain turns off for a few seconds due to a brief shut-down in our arousal system, or lapses of sustained attention, which can occur even when a person is not drowsy. Our Lapse Research Programme's long-term goals are broadly (1) detection and prediction of lapses from electrophysiological and video data, (2) characteristics of lapses, such as rate, duration, changes over time, and differences between individuals, (3) underlying mechanisms in the brain, and (4) factors affecting propensity to lapse.

Amol (supervised by Richard, Phil, Paul Davidson, and Richard Green) submitted his thesis and was awarded his ME on a computer-vision-based system he developed for automated



Figure 2. A participant, just before fully entering the scanner, with the MagLink 64-ch. EEG cap, the Avotec binocular video display & eye camera, and the 2-D joystick (all MR-compatible).

detection of drowsiness and lapses by measuring eye closure from video images of a person's face.

Govinda (supervised by Richard, Carrie, and Phil) has made great progress towards finding out just what happens in the brain during lapses. His PhD project is investigating lapses via fMRI, 64-channel EEG, video of eyes, and visuomotor performance on a continuous 2D tracking task – all being carried out concurrently in a 3T MRI scanner for 50 min (Figure 2).

With Lottery Health Research funding, we have completed collection of data from 20 subjects. Despite the loud noise in the scanner (even with ear-plugs), 16 of our non-sleep-deprived subjects had microsleeps during their afternoon sessions, with an average 90 microsleeps per hour! Analysis of the fMRI data has proven a mammoth task, with analysis of the EEG being put on-hold in the interim. Because slow eye-closure and sudden task non-responsiveness are strong behavioural indicators of microsleeps, Govinda has put a lot of work into understanding and quantifying the brain mechanisms underlying voluntary slow-eye-closure and task non-responsiveness during a visuomotor task. The results from this are important precursors in the investigation of the neural correlates of microsleeps. We have preliminary group results of areas in the brain which have increased and decreased activity during microsleeps, as well as time-courses in areas of particular interest (Figure 3). Understanding just what happens in the brain between cortical arousal, attention, default mode, and other networks in the brain during lapses is of considerable interest in its own right but also has the potential to provide important information for use in substantially improving the accuracy of detection and, possibly, prediction of lapses solely from the EEG or in combination with video of the eyes. We have the only system in NZ able to carry out simultaneous fMRI+EEG investigations of the brain and consider sim-fMRI+EEG to be the ultimate tool for non-invasive investigation of the brain.

Carrie has contributed substantially to the sim-fMRI+EEG study, particularly in the demanding and time-consuming process of rating the simultaneous tracking and eye-video data for lapses. She also has a particular interest in (1) the behavioural characteristics of lapses, (2) what happens in the brain near the *end* of lapses, aimed at answering the question 'Once a person has gone into a microsleep, why does he/she come out of it rather than continue to meet the brain's presumed drive to sleep?', and (3) the effect of sleep deprivation on reasoning and decision-making.

Our new Marsden-funded project will allow us to use combined fMRI, EEG, and behavioural analyses to address important questions about (1) the timing and order of brain activity underlying lapses, (2) the mechanisms underlying the initiation and recovery from lapses, (3) the underlying differences between microsleeps and lapses of attention, and (4) how all of these are affected by sleep deprivation. The main study will also incorporate, and look at differences in lapse propensity between, tasks of continuous tracking, discrete vigilance, and reasoning.

Two other projects have begun this year: Russ (supervised by Richard, John, Carrie, and Deak), has commenced his MA in Psychology project in which he will be looking at the effect of task type (tracking vs. vigilance) and task complexity (easy vs. demanding) on propensity for microsleeps and attention lapses. In the second project, Jie Chen (supervised by Richard, Phil, and Govinda) is doing his BE(Elect) project aimed at automating the time-consuming human-expert rating of tracking performance and video of eyes for detection of lapses and their start- and end-points.

Overall, our Lapse Research Programme will advance scientific understanding of what happens in the brain before and during lapses. In addition, we also believe our research has the potential to lead to the saving of many lives, particularly in the transport sectors, by helping the development of technology to prevent serious accidents due to lapses.

During the past year, Govinda presented papers at *EMBC'08* (Vancouver) and *EPSM'08*, Carrie at *AWCBR'08*, and Richard at *EMBC'08*. Govinda has submitted a paper for publication and is currently working solidly on his PhD thesis.

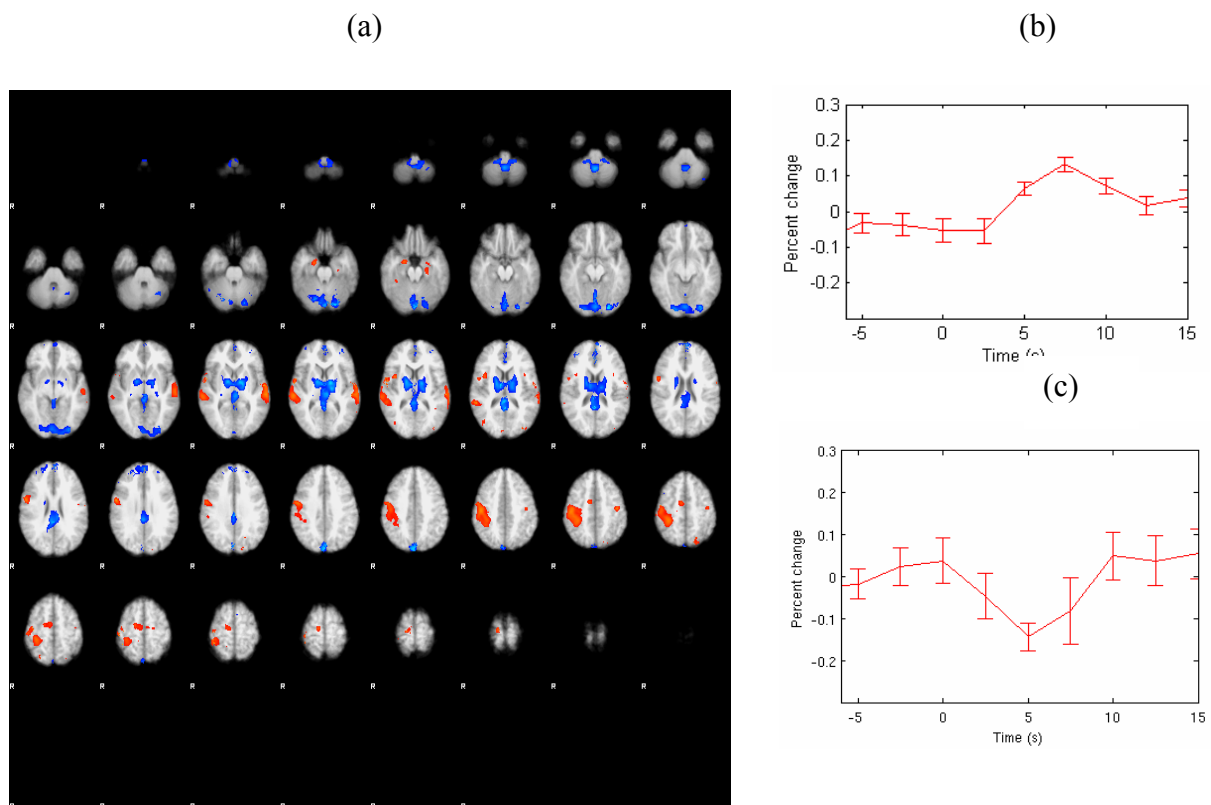


Figure 3. (a) Increased activity (Red) and decreased activity (Blue) in multiple brain areas during microsleeps. (b) Time-courses of increased activity in precentral gyrus. (c) Time-course of decreased activity in right thalamus.

C. Traumatic Brain Injury Research Programme

Marcus's research into the subtle/sub-clinical motor deficits which occur following mild TBI continues strongly. Together with Tim and Richard, he has shown that some of these deficits will not have completely recovered several months after the accident. In a mammoth study, Marcus has collected longitudinal eye movement and health status data from 250 mild TBI patients over the 6 months following their accidents. He has also collected eye movement, health status, and neuropsychological data from 36 patients with postconcussion syndrome (from Burwood Hospital's Head Injury Clinic) and 36 matched mild TBI patients of similar injury severity but good recovery. This has demonstrated the value of measurement of oculomotor function in PCS patients with high symptom loads. A further study is well advanced in which advanced MR imaging techniques are being used to study anatomical and physiological changes in persons who have sustained a mild TBI.

Over the past year, Marcus has presented papers at *FENS'08* (Geneva), *AWCBB'08* (Queenstown), and *EPSM'08*, and Richard at *EMBC'08* (Vancouver). A paper has been submitted for publication on the Burwood PCS study.

D. Virtual-Environment Neurorehabilitation Research Programme

The data collection phase of Daniel's (supervised by Richard and Tim) and Michael's major research study of 24 patients with Parkinson's disease and matched controls is complete and data analysis well advanced. The study involved 4 sessions per subject, several movement and adaptation paradigms (including visual- & memory-guided movements and response delays), ballistic and smooth arm movements, and on- and off-medication – all carried out in Daniel's 3-D multi-sensor/multi-display virtual-environment system. Amongst other things, the study has shown that Parkinson's patients retain artificially-induced changes in their arm dynamics substantially longer than control subjects. This has the potential for development of a novel neurorehabilitation approach to movement dysfunction in persons with Parkinson's disease. Daniel's analysis also includes a technique for decomposing what can look to be bumpy single-step/reaching movements into series of submovements – this looks to be an important means for understanding the underlying causes of differences in reaching tasks between Parkinson's and normal subjects.

Over the past year, Daniel has had a paper published in *IEEE Transactions on Neural Systems and Rehabilitation Engineering* and presented papers at *AWCBB'08* and *EPSM'08*. Richard has presented at *EMBC'08*. Daniel's PhD thesis is well advanced.

Publications & Presentations

Full papers in refereed journals –

Innes CRH, Jones RD, Anderson TJ, Hollobon SG, Dalrymple-Alford JC (2009) Performance in normal subjects on a novel battery of driving-related sensory-motor and cognitive tests. *Behavior Research Methods*, 42(1), 284-294.

Myall DJ, MacAskill MR, Davidson PR, Anderson TJ, Jones RD (2008). Design of a modular and low-latency virtual-environment platform for applications in motor adaptation research, neurological disorders, and neurorehabilitation. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 16: 298-309.

Van Hese P, Vanrumste B, Hallez H, Carroll GJ, Vonck K, Jones RD, Bones PJ, D'Asseler Y, Lemahieu I (2008). Detection of focal epileptiform events in the EEG by spatio-temporal dipole clustering. *Clinical Neurophysiology*, 119: 1756-1770.

Full Papers in Published Conference Proceedings –

Heitger MH, Jones RD, Anderson TJ (Aug 2008). A new approach to predicting postconcussion syndrome after mild traumatic brain injury based upon eye movement function. *Proceedings of 30th Annual International Conference of IEEE Engineering in Medicine and Biology Society (EMBC 2008)*, Vancouver, Canada, 30, 3570-3573.

Myall DJ, MacAskill MR, Anderson TJ, Jones RD (Aug 2008). Submovements in visually-guided and memory-guided reaching tasks: changes in Parkinson's disease. *Proceedings of 30th Annual International Conference of IEEE Engineering in Medicine and Biology Society (EMBC 2008)*, Vancouver, Canada, 30, 1761-1764.

Peiris MT, Jones RD, Davidson PR, Bones PJ (Aug 2008). Event-based detection of lapses of responsiveness. *Proceedings of 30th Annual International Conference of IEEE Engineering in Medicine and Biology Society (EMBC 2008)*, Vancouver, Canada, 30, 4960-4963.

Poudel GR, Jones RD, Innes CRH, Davidson PR, Watts R, Bones PJ, Signal TL (Aug 2008). Functional-MRI correlates of cued slow-eye-closure and task non-responsiveness during visuomotor tracking. *Proceedings of 30th Annual International Conference of IEEE Engineering in Medicine and Biology Society (EMBC 2008)*, Vancouver, Canada, 30, 4122-4125.

Published Abstracts –

Heitger M, Jones R, Macleod A, Snell D, Wilson I, Anderson T (2008). A novel biomarker of postconcussion syndrome. (Abstract) *Australasian Physical & Engineering Sciences in Medicine*, 31, 486-487.

[Presented at *Engineering and Physical Sciences in Medicine and the Australian Biomedical Engineering Conference 2008 (EPSM-ABEC 2008)*, Christchurch, Nov 2008]

Hoggarth P, Innes C, Dalrymple-Alford J, Jones R. (2009). A nonlinear model of cognitive and sensory-motor test performance can aid in prediction of on-road driving ability in older adults. (Abstract). *Proceedings of Annual Meeting of International Neuropsychological Society*, Atlanta 2009;37: http://medicine.osu.edu/sitetool/sites/pdfs/inspublic/final_program_linked_abstracts.pdf, 228.

Innes C, Jones R, Dalrymple-Alford J, Severinsen J, Gray J (2008). Prediction of driving ability in people with dementia and non dementia related brain disorders is more accurate when based upon different models of sensory-motor and cognitive performance. (Abstract) *Australasian Physical & Engineering Sciences in Medicine*, 31, 431-432.

[Presented at *Engineering and Physical Sciences in Medicine and the Australian Biomedical Engineering Conference 2008 (EPSM-ABEC 2008)*, Christchurch, Nov 2008]

Myall D, MacAskill M, Davidson P, Anderson T, Jones R (2008). A modular low-latency virtual-environment platform for applications in motor adaptation research, neurological disorders, and neurorehabilitation. (Abstract) *Australasian Physical & Engineering Sciences in Medicine*, 31, 359.

[Presented at *Engineering and Physical Sciences in Medicine and the Australian Biomedical Engineering Conference 2008 (EPSM-ABEC 2008)*, Christchurch, Nov 2008]

Myall D, MacAskill M, Anderson T, Jones R (2008). Submovements in reaching tasks: the effect of Parkinson's disease. (Abstract) *Australasian Physical & Engineering Sciences in Medicine*, 31, 372-373.

[Presented at *Engineering and Physical Sciences in Medicine and the Australian Biomedical Engineering Conference 2008 (EPSM-ABEC 2008)*, Christchurch, Nov 2008]

Poudel G, Jones R, Innes C, Davidson P, Watts R, Signal L, Bones P (2008). Increased multisensory activity during cued slow-eye-closure while performing a visuomotor tracking task: an fMRI study. (Abstract) *Australasian Physical & Engineering Sciences in Medicine*, 31, 488-489. [Presented at *Engineering and Physical Sciences in Medicine and the Australian Biomedical Engineering Conference 2008* (EPSM-ABEC 2008), Christchurch, Nov 2008]

Poudel G, Jones R, Innes C (2008). A 2-D pursuit tracking task for behavioural detection of lapses (Abstract) *Australasian Physical & Engineering Sciences in Medicine*, 31, 528-529. [Presented at *Engineering and Physical Sciences in Medicine and the Australian Biomedical Engineering Conference 2008* (EPSM-ABEC 2008), Christchurch, Nov 2008]

Conference Presentations –

Heitger MH, Jones RD, Macleod AD, Snell D, Wilson I, Anderson TJ (July 2008). Eye movement deficits in postconcussion syndrome (Abstract). *Proceedings of Federation of European Neuroscience Societies (FENS)*, Geneva, Switzerland, 4, 084.6.

Heitger MH, Jones RD, Macleod AD, Snell D, Wilson I, Anderson TJ (Aug 2008). Eye movements – functional markers of incomplete recovery in postconcussion syndrome. (Abstract) *Proceedings of the International Australasian Winter Conference on Brain Research*, 26, #9.5.

Hoggarth P, Innes C, Dalrymple-Alford J, Jones R (Aug 2008). Cognitive and sensory-motor performance cannot fully predict unsafe driving in healthy older drivers (Abstract). *Proceedings of Annual Conference of the New Zealand Psychology Society*, Christchurch, 42.

Hoggarth P, Jones R, Innes C, Dalrymple-Alford J (Sep 2008). The complex task of predicting driving ability in healthy older adults. (Abstract) *University of Canterbury Postgraduate Research Showcase*.

Jones RD (Jun 2008). Neurotechnology research. *1st Annual Conference of New Zealand Hospital Scientific Officers' Association*, Christchurch, 4.

Innes CRH, Jones RD, Dalrymple-Alford JC, Severinsen J, Gray J (Aug 2008). Separate models for people with dementia or other brain disorders increase the accuracy of classifying on-road pass or fail based on sensory-motor and cognitive tests. (Abstract) *Proceedings of the International Australasian Winter Conference on Brain Research*, 26, #4.26.

Innes CRH, Poudel GR, Watts R, Bones PJ, Dalrymple-Alford JC, Jones RD (Aug 2008). Investigation of lapses of responsiveness via simultaneous fMRI and EEG. (Abstract) *Proceedings of the International Australasian Winter Conference on Brain Research*, 26, #5.4.

Myall DJ, MacAskill MR, Anderson TJ, Jones RD (Aug 2008). Visuomotor adaptation after-effects in Parkinson's disease. (Abstract) *Proceedings of the International Australasian Winter Conference on Brain Research*, 26, #4.28.

Poudel GR, Jones RD, Innes CR, Bones PJ. (June 2008). Characteristics and EEG spectral dynamics of behavioural microsleeps in a mock-MRI scanner. (Abstract) *Proceedings of Annual Conference of Human Brain Mapping (HBM 2008)*, Melbourne, Australia, 14.
