ANS-AuPS SENSORIMOTOR SATELLITE MEETING
Saturday & Sunday, 30-31 January 2010
The John Dwyer Lecture Theatre, Edmund Blacket Building,
Prince of Wales Hospital
Prince of Wales Medical Research Institute

Saturday, 30th January

8.30-8.50	**Registration and Morning Coffee**
8.50-9.00	**Welcome and Introduction – Simon Gandevia**
Session 1:	**Hand Matters** **Chair: Vaughan Macefield**
9.00-9.25	**Mary GALEA (Uni Melb)** **Upper limb function following stroke**
9.25-9.50	**Tony GOODWIN (Uni Melb)** **Cutaneous afferents and hand function**
9.50-10.05	**Ingvars BIRZNIEKS (POWMRI)** **Tactile sensory input: speed and real-time concurrent stimulus parameter discrimination**
10.05-10.20	**Stephen REDMOND (UNSW)** **Design of tactile sensors**
10.20-10.35	**Hiske VAN DUINEN (POWMRI)** **Short-term synchronization between an intrinsic and an extrinsic hand muscle**
10.35-10.50	**Jason FRIEDMAN (Macquarie U)** **Temporal dynamics of decision making revealed through the submovement decomposition of hand trajectories**
10.50-11.15	**Morning Tea**
Session 2:	**Cortical Matters** **Chair: Mike Ridding**
11.15-11.40	**John DONOGHUE (Brown University, Rhode Island, USA)** **What is represented in M1?**
11.40-12.05	**John ROTHWELL (Institute of Neurology, London, UK)** **Probing and manipulating movement-related inputs to human motor cortex**
12.05-12.30	**Cathy STINEAR (University of Auckland, New Zealand)** **Flexor synergy after stroke: contributions of contralateral and ipsilateral M1 projections**

12.30-12.45	**Robin CASH (UWA)** **Cortical inhibition, disinhibition and I-wave facilitation in human motor cortex**
12.45-1.00	**Shapour JABERZADEH (Monash U)** **Corticospinal control of trunk muscles is task-dependent**
1.00-2.00	**Lunch**
Session 3:	
2.00-3.00	**Poster Viewing [odd numbers]**
3.00-4.00	**Poster Viewing [even numbers]**
3.30-4.00	**Afternoon Tea**
Session 4:	**Neurorespiratory Matters** **Chair: Simon Gandevia**
4.00-4.25	**Paul PILOWSKY (Macquarie U)** **A pharmacological dissection of the central cardiorespiratory system**
4.25-4.50	**Gary SIECK (Mayo Clinic, Rochester, USA)** **Targeting phrenic motor neuron neuroplasticity to promote recovery after cervical spinal cord injury**
4.50-5.15	**Mark BELLINGHAM (U Qld)** **Maintaining an open airway – neuromodulator regulation of hypoglossal motor neuron activity**
5.15-5.30	**Jane BUTLER (POWMRI)** **Behaviour of human genioglossus motoneurones**
5.30-5.45	**Anna HUDSON (POWMRI)** **Respiratory and non-respiratory drive to human intercostal motoneurones**
5.45-6.00	**Discussion**
6.00-8.30	**Drinks and Informal Dinner** **Venue: Prince of Wales Medical Research Institute**

Sunday, 31st January

8.45-9.00	**Check In and Morning Coffee**
Session 5:	**Afferent Matters** **Chair: Uwe Proske**
9.00-9.25	**Tanja SEIZOVA-CAJIC (U Syd)** **Adaptation in human proprioception**

9.25-9.50	**Trevor ALLEN (Monash)** **Disturbances to position sense after muscle fatigue**
9.50-10.05	**Lee WALSH (POWMRI)** **Moving a phantom hand**
10.05-10.20	**Serajul KHAN (U Syd/POWMRI)** **Possible tendon organ inhibition in human gastrocnemius**
10.20-10.35	**Kylie Tucker (UQld)** **Pain alone does not interfere with motor cortical plasticity**
10.35-10.50	**Lorimer MOSELEY (POWMRI)** **Intriguing relationships between body image, motor output, pain and autonomic control**
10.50-11.15	**Morning Tea**
Session 6:	**Efferent Matters** **Chair: Janet Taylor**
11.15-11.40	**John SEMMLER (Uni Adelaide)** **Training-related changes in human motor unit activity**
11.40-12.05	**Dario FARINA (Aalborg, Denmark)** **Relation between low-frequency components in motor unit discharge rates, force and the EEG**
12.05-12.20	**Tjeerd BOONSTRA (BDI)** **Can neural synchronization differentiate between sources of descending input to a motoneurone pool?**
12.20-12.35	**Richard FITZPATRICK (POWMRI)** **Cortical and non-cortical muscle activation for balance**
12.35-12.50	**Jim COLEBATCH (POWH)** **Properties of rectified averages**
12.50-1.00	**Discussion and Close**

2.00-4.00	**Informal workshop for those using CED products (eg. Spike and Signal)** **Numbers are limited for this workshop** **Organizer: Penelope McNulty** **Venue: POWMRI BOARD ROOM** **Barker Street, Randwick, NSW 2031**

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Saturday, 30th January

Session 1: Hand Matters 9.00 – 10.50 am

UPPER LIMB FUNCTION FOLLOWING STROKE

Galea MP, Miller KJ, Blennerhassett J, Lythgo ND

Rehabilitation Sciences Research Centre, The University of Melbourne and Austin Health, Parkville, VIC

Functional recovery of the paretic upper limb after stroke continues to be one of the greatest challenges faced by rehabilitation professionals. Predictive models suggest that the prognosis for recovery of upper limb function is poor if the affected upper limb remains severely impaired in the first four weeks post-stroke. As a result, the expectations for recovery in individuals with poor upper limb function are low, particularly if they have little movement to work with. In a pilot study in patients with severe upper limb impairment we have shown that early task-specific training, commenced within the first six weeks post-stroke, is effective in reducing arm and hand impairments and improving function compared with a control intervention. Early reduction of impairment, especially of shoulder function, can provide a solid foundation for ongoing improvement and better long-term outcome. Our findings challenge previously held assumptions regarding upper limb prognosis, and the feasibility of applying task-oriented training principles in the low-functioning upper limb following stroke.
Another factor associated with poor recovery after stroke is the development of shoulder pain. Although attributed to subluxation of the glenohumeral joint, shoulder pain is associated with poor quality of movement of the shoulder girdle. Three-dimensional analysis of shoulder movements has shown that the affected shoulder exhibits disordered patterns of abduction and flexion relative to the non-affected side, associated with poor control of scapular motion. This type of movement impairment, if persistent, may contribute to the development of shoulder pain because of soft tissue impingement, and highlights the need for specific retraining of scapular movement.

CUTANEOUS AFFERENTS AND HAND FUNCTION

Tony Goodwin

University of Melbourne

TACTILE SENSORY INPUT: SPEED AND REAL-TIME CONCURRENT STIMULUS PARAMETER DISCRIMINATION

Ingvars Birznieks

Prince of Wales Medical Research Institute, Sydney

The efficiency of motor control strategies largely rests on highly selective specialised sensory inputs which signal mechanical events relevant for hand function during various tasks. Clever peripheral information-encoding mechanisms and receptor properties determine the speed, reliability and computational power requirements for extraction of sensory information and usage for motor control. For example, to gain speed the population of tactile afferents can signal dynamic mechanical fingertip events using a neuronal code based solely on the first-spike latency. This is the fastest known mechanism to transmit information to the CNS. Moreover, the CNS can obtain accurate sensory information about multiple tactile stimulus parameters, despite the fact that each parameter simultaneously acts on the same afferent populations, creating potentially confounding interaction effects. Furthermore, this process has to happen as fast as possible to avoid loss of the gripped object and ensure smooth manipulation. How such concurrent stimulus parameters can be disentangled has been an unresolved fundamental question in tactile research. We addressed these issues by modelling tactile afferent responses using a Parzen window classifier and corresponding learning algorithms. Thus we could demonstrate the capacity of the tactile afferent populations to discriminate multiple stimulus parameters - concurrently and in real-time. We believe that understanding afferent encoding mechanisms and being able to interpret information

recorded from the peripheral nerves is an important step towards incorporating sensory-driven control algorithms into prosthesis and functional electrical stimulation devices, ultimately assisting patients to regain hand function.

DESIGN OF TACTILE SENSORS

Stephen Redmond

School of Electrical Engineering and Telecommunications, University of New South Wales

The lack of adoption, in the industrial environment, of robotic manipulators for dexterous manipulation, in addition to the relative inability of prosthetic limb users to perform delicate tactile maneuvers, can be attributed in part to the paucity of suitable sensor modalities available to provide the requisite richness of sensory feedback information, which would facilitate such dexterous control. Typically the use of existing commercial tactile sensors is limited by: cost, robustness, form factor, accuracy, response time, and stability and repeatability.
At the University of New South Wales (UNSW), under the umbrella of the Australian Research Council's Thinking Systems Project, we have engaged in several fledgling projects to investigate the suitability of various sensor transduction modalities and materials and sensor structures to meet the challenges outlined above, in this area of growing importance.
This presentation will provide a brief overview of the standard transduction approaches used in existing tactile sensor designs and continue by illustrating some early prototypes under development at UNSW, and outlining some speculated future research avenues.

SHORT-TERM SYNCHRONIZATION BETWEEN AN INTRINSIC AND AN EXTRINSIC HAND MUSCLE

Hiske van Duinen[1]*, Simon C Gandevia[1], Andrew J Fuglevand[2]

[1]Prince of Wales Medical Research Institute, Sydney, Australia; [2]Dept. Physiology, University of Arizona, Tucson, USA

When we use our hands, many muscles are activated simultaneously. However, it is unknown how the brain precisely coordinates the activity of these muscles. One way to link the muscles would be to send common input to motoneurons supplying different muscles. A sign of common input is short-term synchronization, the coincident firing of pairs of motor units (6). It is present within and across extrinsic hand muscles and muscle compartments (1,2,3,7) and within, but not across, intrinsic hand muscles (4). For many movements, both intrinsic and extrinsic muscles are active simultaneously, e.g. during index finger flexion. We assessed whether common input links extrinsic and intrinsic muscles during index finger flexion. Eight subjects performed weak isometric flexion of the index finger for 3-5 minutes. We recorded motor unit activity from the index finger compartment of the extrinsic muscle flexor digitorum superficialis (FDS) and the intrinsic muscle first dorsal interosseous (FDI), using two microelectrodes per muscle. Cross-correlation histograms were constructed for within-muscle and across-muscle motor unit pairs. The common input strength index (CIS; 5) representing the degree of short-term synchrony was calculated. We recorded 26 FDS-FDS, 26 FDI-FDI, and 84 FDS-FDI motor unit pairs with CIS values of 0.36±0.33, 0.40±0.24, and 0.086±0.10, respectively. Thus, there was substantial within-muscle but little across-muscle synchronization for FDS and FDI suggesting that their coordinated activity during index finger flexion is not a consequence of divergent descending inputs providing common input to their motor nuclei.

1. Hockensmith GB, Lowell SY, Fuglevand AJ. 2005. J Neurosci 25: 4560–4564
2. Keen DA, Fuglevand AJ. 2004. J Neurophysiol 91: 57–62
3. McIsaac TL, Fuglevand AJ. 2007. J Neurophysiol 97: 550-556
4. McIsaac TL, Fuglevand AJ. 2008. Exp Brain Res 188:159–164
5. Nordstrom MA, Fuglevand AJ, Enoka RM. J Physiol 453: 547–574, 1992.
6. Sears TA, Stagg D. 1976. J Physiol 263: 357–381
7. Winges SA, Santello M. 2004. J Neurophysiol 92: 3210–3220
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TEMPORAL DYNAMICS OF DECISION MAKING REVEALED THROUGH THE SUBMOVEMENT DECOMPOSITION OF HAND TRAJECTORIES

Jason Friedman & Matthew Finkbeiner

Macquarie Centre for Cognitive Science (MACCS), Macquarie University

The segmentation of seemingly continuous movements into overlapping submovements with bell-shaped velocity profiles has been theorised for many years. In this study, we decomposed into submovements the hand trajectories of subjects that were required to point to a target in the direction (left or right) that the majority of a set of random dots were moving, under differing levels of coherence (the proportion of dots that move together).

Under the assumption that submovements are executed in a feed-forward manner, we can infer that the entire submovement is already planned at its onset, and so the parameters that describe the submovement may reveal the intention at that time. For the arm movements in this study, it was found that the timing and amplitude of the submovements are related to the expected amount of perceptual information available at submovement onset. Rather than waiting for a definitive decision to one target or the other, the arm trajectories as observed through the submovement amplitudes reflect the current partial information at their onset time. These findings show the extent that incomplete perceptual information affects movements. The results are presented in the context of a cognitive model of decision making.

Session 2: Cortical Matters 11.15 am – 1.00 pm

WHAT IS REPRESENTED IN M1? LOCAL MI ENSEMBLES FOR REACHING AND GRASPING

John Donoghue

Providence VA Medical Center and Brown Institute for Brain Science, Brown University, Providence RI, USA 02912

How populations of neurons in motor cortex participate in coordinated multi-joint actions of the arm, wrist and hand remains poorly understood. To examine the role of local MI ensembles in natural reach and grasp actions, we combined multielectrode recording with a 12-camera, full arm motion capture system (Vicon). Rhesus monkeys were trained to reach for and grasp up to 9 differently shaped solid objects swinging on a string unpredictably in front of them. The task elicited a diverse set of behaviors requiring about 10 degrees of freedom across 25 joints (shoulder to finger ip joints) to perform. The firing rate of individual MI neurons within a 4 x 4 mm region of the MI arm area was typically modulated by the kinematics of multiple joints with no clear-cut spatial topography for distal or proximal joints. Local MI ensembles contained sufficient information to reconstruct arm, wrist and hand actions, including the hand's location in space and finger aperture. Beyond showing that the spiking patterns of local MI ensembles represent a rich set of movements involving the entire upper limb, the results also suggest that achieving high dimensional reach and grasp actions with neuroprosthetic devices may be possible using small intracortical arrays like those already being tested in the BrainGate human pilot clinical trial.

PROBING AND MANIPULATING MOVEMENT-RELATED INPUTS TO HUMAN MOTOR CORTEX

John Rothwell, Marco Davare, Roger Lemon

UCL Institute of Neurology, London, UK

Double pulse transcranial magnetic stimulation (TMS) experiments have proved useful in probing how the excitability of inputs to motor cortex changes during the performance of different tasks. For example, input from dorsal premotor cortex (PMd) is modulated during reaction tasks involving choices between symbolic movement cues. In contrast, input from ventral premotor cortex (PMv) is modulated during preparation for grasping visual objects using particular hand postures.

The question we addressed in the present experiments was whether it would be possible to follow the sequences of input into motor cortex one stage further. We tested how task-related connectivity from PMv-M1 is modulated by temporary interference ("virtual lesion") with one of its main input structures, the anterior intraparietal cortex (AIP).

The anterior intraparietal cortex (AIP) is thought to provide task related information about the object to be grasped to PMv. We tested the hypothesis that this would be important in setting up the correct, muscle specific, pattern of interactions between PMv-M1. Continuous theta burst TMS was used to produce a "virtual lesion" of AIP. This caused a reduction in the task-related changes in connectivity from PMv-M1 that correlated with decreased specificity in the pattern of EMG activity that was required to manipulate the object. There was no effect on the PMv-M1 connectivity tested at rest nor on the excitability of M1 itself. These findings suggest that grasp-related and muscle-specific PMv-M1 interactions are driven by information about object properties provided by AIP. They show that it may be possible to use TMS to track the flow of information into the motor system from multiple converging sources.

FLEXOR SYNERGY AFTER STROKE: CONTRIBUTIONS OF CONTRALATERAL AND IPSILATERAL M1 PROJECTIONS

Cathy M. Stinear[1,3], Lynley V. Bradnam[2,3], Winston D. Byblow[2,3]

1 Neurology Research Unit, Department of Medicine, University of Auckland
2 Movement Neuroscience Laboratory, University of Auckland
3 Centre for Brain Research, University of Auckland

Abnormal muscle synergies after stroke restrict hand and arm function. Failure of the primary motor cortex (M1) to suppress activation of antagonist muscles may explain aberrant synergy formation. This study aimed to identify whether abnormal muscle synergies originate in the hemisphere that is contralateral or ipsilateral to the affected arm.
Excitability of the left M1 was suppressed in healthy adults by repetitive transcranial magnetic stimulation (TMS) in continuous theta burst stimulation (cTBS). Contralateral motor evoked potentials (cMEPs) were elicited in left and right biceps brachii (BB) prior to elbow flexion or forearm pronation. An excitability ratio was used as an index of motor synergy based on the amplitude of BB cMEPs prior to pronation compared to flexion. Short interval intracortical inhibition (sICI) was assessed in right BB with paired-pulse TMS of left M1. Ipsilateral MEPs and silent periods were measured in left BB with single-pulse TMS of left M1.
After cTBS, the BB excitability ratio increased bilaterally. In the right arm the ratio increased because BB cMEPs prior to flexion were suppressed, accompanied by an increase in sICI. In the left arm the ratio increased because BB cMEPs prior to pronation were facilitated, consistent with an abnormal synergy. This was associated with facilitation of left BB ipsilateral MEPs.
The synergy-specific effects indicate descending inhibition from ipsilateral M1 to spinal motoneurons (MNs) was reduced following cTBS. Decreased descending inhibition from the contralesional hemisphere may have an important role in the formation of abnormal synergies after stroke.

CORTICAL INHIBITION, DISINHIBITION AND I-WAVE FACILITATION IN HUMAN MOTOR CORTEX

Robin Cash[1], Ulf Ziemann[2], Gary Thickbroom[1]

[1]Centre for Neuromuscular and Neurological Disorders, University of Western Australia
[2]Department of Neurology, Goethe-University of Frankfurt, Germany

The activation of inhibitory interneurones by a single supra-threshold TMS gives rise to post-synaptic inhibition (short- and long-interval), as well as disinhibition probably mediated by pre-synaptic GABAb receptors that limit further GABA release. Using a triple-pulse TMS technique, we have explored the relative time-course of disinhibition and inhibition as well as their effects on excitatory circuits. We hypothesized, based on cellular reports, that disinhibition would outlast inhibition, leading to a late period of increased excitability. Disinhibition was investigated by measuring the reduction in the strength of short-interval intracortical inhibition (SICI), in the range 100-300ms after a supra-threshold priming stimulus (PS). The effect of the PS on corticomotor excitability was determined with single test stimuli (TS), and short-interval cortical facilitation (SICF; 1.5ms) measurements made at the same intervals after PS. SICI was significantly reduced up to 220ms after PS. TS MEP amplitude was initially significantly reduced up to 150ms post PS ($p<0.01$), but then increased above baseline in the range 190-210ms, reaching 160$\pm$17% of baseline 200ms after PS ($p<0.01$). SICF was enhanced up to 189+29% of baseline in the range 190-220ms ($p<0.01$). We conclude that disinhibition is longer lasting than inhibition, leading to a period that we refer to as late cortical disinhibition (LCD), and correspondingly a period of increased corticomotor excitability. The identification of LCD in human motor cortex may provide an opportunity to explore or modulate the behaviour of excitatory networks at a time when inhibitory effects are restrained.

CORTICOSPINAL FACILITATION OF ERECTOR SPINAE AND RECTUS ABDOMINUS MUSCLES DURING GRADED VOLUNTARY CONTRACTIONS ARE TASK SPECIFIC: A PILOT STUDY ON HEALTHY INDIVIDUALS

Shapour Jaberzadeh[a], Maryam Zoghi[b], Prue Morgan[a], Michael Storr[a]

a: Department of Physiotherapy, School of Primary Health Care, Monash University, Melbourne, Australia.
b: Rehabilitation Sciences Research Centre, University of Melbourne, Melbourne, Australia.

Using transcranial magnetic stimulation (TMS) of the left motor cortex, we aimed to compare simultaneous patterns of corticospinal facilitation of the contralateral erector spinae (ES) and rectus abdominis (RA) muscles during graded voluntary activation in a postural (bilateral trunk extension; BTE) and a respiratory task (forced expiration during a breath holding task; FEBH). Threshold to TMS was determined when the subjects were sitting in a comfortable podiatry chair maintaining a weak contraction (15% MVC). Subsequent experimental trials were conducted using a stimulus intensity of 1.2 times this threshold value which evoked simultaneous

responses in both muscles in all 7 healthy volunteers. The MEPs had short latencies; right ES: 15.4±0.75 ms (BTE task) and 15.49±0.95 ms (FEBH task), right RA: 18.17±1.3 ms (BTE task) and 18.64±0.95 ms (FEBH task) which are consistent with other studies suggesting a fast corticospinal input to the trunk muscles. The facilitation pattern in the current study did suggest a task dependency in that MEP amplitudes in ES muscle tended to be smaller at any given contraction level in the FEBH task than in the BTE task. The results indicated that unlike the linear relationship between the size of MEPs with increasing background contraction of ES and RA in BTE task, more or less; both muscles showed a plateau effect in higher background contractions (50% of maximum) during FEBH task. In conclusion, unlike the BTE task where the level of facilitation in both muscles linearly depended on the levels of background contraction, during FEBH both ES and RA muscles have a facilitation pattern similar to that previously shown in hand muscles - but unlike hand muscles maximum facilitation occurred at 50% of maximum voluntary contraction and above.

Session 4: Neurorespiratory Matters 4.00 – 6.00 pm

A PHARMACOLOGICAL DISSECTION OF THE CENTRAL CARDIORESPIRATORY SYSTEM

Paul Pilowsky

Macquarie University, ASAM, Faculty of Human Sciences.

Central regulation of the cardiorespiratory system needs to achieve several crucial aims. First, maintenance of a satisfactory level of blood pressure in order to allow supply of oxygen to organs such as the brain that autoregulate their own blood supply. Secondly, the brain must be responsive to changes in blood pressure, oxygen, blood acid and other metabolic and sensory states in order to reflexly control and maintain blood pressure at a stable level in the face of central command and changes in peripheral state.

The principal site which this tonic and reflex organisation is integrated is the rostral ventrolateral medulla (RVLM). Columns of cells that start at the level of facial nucleus rostrally and are arranged in nuclei caudally from this point control sympathetic and parasympathetic nerve activity, tracheal and laryngeal function and motor control of the oesophagus. Acute lesions of this region are uniformly lethal.

Neurons in the RVLM interact to produce a normal respiratory rhythm that controls the phrenic motoneurons and a tonic level of sympathetic nerve activity that can be manipulated centrally, and by peripheral inputs. This regulation is achieved on a moment to moment basis by the appropriate synaptic release of fast neurotransmitters including glutamate, GABA and glycine acting at ligand gated channels. Longer term control of neuronal function in this region can be achieved through pre- and post- synaptic action of ligands such as peptides that act at metabotropic receptors.

It is the action of the more slowly acting ligands, including PACAP, galanin and somatostatin in cardiorespiratory regulation that will be the topic of my talk.

TARGETING PHRENIC MOTOR NEURON NEUROPLASTICITY TO PROMOTE RECOVERY AFTER CERVICAL SPINAL CORD INJURY

Gary Sieck

Department of Physiology & Biomedical Engineering, Mayo Clinic

In the United States there are about 11,000 new cases of spinal cord injury (SCI) each year. Most SCI's are incomplete with some sparing of spinal cord pathways. Among SCI patients, ~50% involve the cervical spinal cord, with many cases resulting in impairment of rhythmic phrenic nerve activity and paralysis of the diaphragm muscle (DIAm). Some of these SCI patients must be maintained on long-term mechanical ventilation, with associated higher morbidity and mortality rates. Clearly, it is important to understand how rhythmic phrenic activity can be restored in these SCI patients and this is a key objective of our research.

It is well established that excitatory premotor drive to phrenic motoneurons emanates predominantly from the ipsilateral medulla. As a result, after C_2 spinal cord hemisection (SH) ipsilateral excitatory input is removed and rhythmic phrenic activity disappears on the affected side. However, there is a latent contralateral excitatory premotor input to phrenic motoneurons that can be strengthened with time after SH (neuroplasticity) leading to functional recovery of rhythmic phrenic activity (crossed phrenic phenomenon). Converging evidence suggests that neurotrophins (e.g., brain-derived neurotrophic factor - BDNF) acting through tropomyosin related kinase receptors (e.g., TrkB) play an important role in neuroplasticity. Importantly, only full-length TrkB (TrkB.FL) is capable of signaling via phosphorylation, whereas truncated TrkB isoforms (TrkB.T1 and TrkB.T2) act in a dominant-negative fashion to inhibit TrkB signaling. Our results indicate that intrathecal BDNF treatment enhances functional recovery of rhythmic phrenic activity, whereas intrathecal treatment with TrkB-Fc, a fusion protein that quenches extracellular BDNF delays functional recovery. Unfortunately, exogenous intrathecal

neurotrophin treatment is associated with significant negative adverse effects that preclude its therapeutic use. As an alternative, we have explored use of a novel targeted approach to promote recovery of rhythmic respiratory activity following cervical SCI by enhancing TrkB.FL expression and signaling in phrenic motoneurons, while avoiding undesirable adverse effects. *Our central hypothesis is that functional recovery of rhythmic phrenic activity after SH is enhanced by an increase in TrkB.FL signaling in phrenic motoneurons*. Our long-term goal is to develop an effective therapy to increase TrkB.FL signaling in phrenic motoneurons and thereby promote functional recovery after upper cervical SCI.

MAINTAINING AN OPEN AIRWAY – NEUROMODULATOR REGULATION OF HYPOGLOSSAL MOTOR NEURON ACTIVITY

Mark Bellingham

School of Biomedical Sciences, University of Queensland, Brisbane, QLD, 4072, Australia

The tongue is a multi-purpose muscle used in breathing, eating and vocalization. One vital function of the tongue is maintenance of an open upper airway. Tonic and phasic activity of the intrinsic tongue muscles is driven by activity in hypoglossal motor neurons. This activity is, in turn, dependent on the actions of multiple neuromodulators (acetylcholine, serotonin, noradrenaline, neuropeptides) on both ionic currents and excitatory/inhibitory synaptic inputs of hypoglossal motor neurons. Release of these neuromodulators is highly state-dependent, varying markedly during different states of wakefulness and sleep.
In normal rodent hypoglossal motor neurons, activation of muscarinic acetylcholine receptors is a potent enhancer of intrinsic excitability, through changes in a suite of ionic currents, including the M current, a linear "leak" current and the hyperpolarization-activated cationic current. Muscarinic receptor activation of motor neurons enhances their firing rate, while muscarinic receptor activation of the respiratory central pattern generation circuitry slows the rate of inspiratory synaptic burst activity in motor neurons.
These independent effects suggest that acetylcholine acting on muscarinic receptors may play a key role in maintaining motor neuron excitability and firing during behavioural states such as rapid eye movement sleep, during which cholinergic neurons are highly active. Deficiencies in cholinergic excitation of upper airway motor neurons may play a significant role in conditions such as sudden infant death syndrome and obstructive sleep apnoea.

BEHAVIOUR OF HUMAN GENIOGLOSSUS MOTONEURONES

Jane Butler

Prince of Wales Medical Research Institute, Randwick, NSW, 2031.

The hypoglossal motor nucleus innervates a number of muscles in the upper airway that are important for maintaining airway patency. Genioglossus (GG), in the tongue, is the largest of these muscles and its contraction pulls the tongue forward and downwards to open the airway. GG is activated during inspiration in humans with some tonic activity in expiration. We have recorded the activity of single motor units from the genioglossus in human subjects (supine) and have found that its pattern of activation is comprised of a complex combination of at least 5 patterns of motoneurone output.
Based on 2 studies (Saboisky et al. 2006, 2007), the majority of units (~70%) discharge phasically or increase their discharge frequency with inspiration (*Inspiratory Phasic* and *Inspiratory Tonic* units). A minority (~10%) increase their discharge during expiration (*Expiratory Phasic* and *Expiratory Tonic* units), while ~20% discharge tonically without respiratory modulation (*Tonic* units). Simultaneous recordings of two or three motor units showed neighboring units with differing respiratory and tonic drives.
Our results suggest this activity results from a complex interaction of inspiratory, expiratory, and tonic drives at the hypoglossal motor nucleus. The presence of different drives to GG implies that complex premotor networks can differentially engage human hypoglossal motoneurons during respiration. This is unlike the ordered recruitment of motor units in limb and axial muscles.

Saboisky et al. (2007). *Journal of Physiology (London)* **585**, 135-146.
Saboisky et al. (2006). *Journal of Neurophysiology* **95,** 2213-2221.

RESPIRATORY AND NON-RESPIRATORY DRIVE TO HUMAN INTERCOSTAL MOTONEURONES

Anna Hudson

Prince of Wales Medical Research Institute and the University of New South Wales

Human parasternal intercostal muscles are obligatory inspiratory muscles and are activated by rhythmic descending input from the medulla. However, these axial muscles also contract in volitional tasks driven by the motor cortex. In separate studies, we have recorded the output from populations of human parasternal

intercostal motoneurones in healthy subjects in multiple tasks, such as quiet breaths, targeted voluntary breaths and voluntary rotations of the trunk. In quiet breaths, there is differential topographic recruitment with significantly greater and earlier activity in the first interspace compared to caudal spaces. This rostrocaudal pattern of activation is preserved in voluntary breaths, but the output of the motoneurones is slightly higher and earlier due, in part, to differences in respiratory variables between quiet and voluntary breaths. The parasternal intercostals on the right side contract in voluntary rotations of the trunk to the right (i.e. ipsilateral rotation), but are silent in rotations to the left (contralateral rotation). There are also direction-dependent effects when respiration is superimposed on a maintained rotation of the trunk. While there are large increases in the amount of activity, recruitment of additional motor units, and earlier onset of inspiratory activity when respiration is superimposed on ipsilateral rotation, there is a reduction in inspiratory activity and number of motor units active, as well as a delay in onset of inspiratory activity, with contralateral rotation. A consideration of the evolution of respiratory muscle control in mammals emphasizes that multiple descending pathways activate the same axial motoneurone pools, and this may have implications for the control of the intercostal muscles in humans. Hence, a likely interpretation of our results is that respiratory and non-respiratory drive to different intercostal muscles (i.e. in different interspaces) is coordinated in the spinal cord.

Sunday, 31st January

Session 5: Afferent Matters 9.00 – 10.50 am

ADAPTATION IN HUMAN PROPRIOCEPTION

Tanja Seizova-Cajic

Faculty of Health Sciences, The University of Sydney

Adaptation to constant stimulation has often been used to investigate the mechanisms of perceptual coding, but little is known about adaptation in the proprioceptive coding of movement. A prolonged movement signal induced by muscle vibration results in an aftereffect, the feeling of a return movement. This proprioceptive movement aftereffect may at least in part be attributed to the adaptation in the muscle spindles, but we show that central processes such as attention also play a role. Another adaptation phenomenon we studied concerns perception of wrist movement, showing for the first time that a prolonged exposure to a passive back-and forth movement of a certain extent results in a dramatic change in judgment of the extent of a subsequently presented movement. Proprioception is thus similar to other perceptual modalities in that it exhibits adaptation effects, which, interesting as they are in their own right, can also be useful as a tool to study perceptual coding mechanisms of different movement parameters.

DISTURBANCES TO LIMB POSITION SENSE AFTER MUSCLE FATIGUE AT THE ELBOW & KNEE

Trevor Allen, Michael Leung, Uwe Proske

Department of Physiology, Monash University, Victoria, Australia.

When human limb position sense is measured in blindfolded subjects using simple position matching tasks, subjects typically match their limbs with an accuracy of < 3 degrees. If one limb is exercised to induce significant (30%) muscle fatigue, we have shown that position sense becomes significantly disturbed. Importantly, the errors occurred in a specific direction depending on which muscle group or joint was exercised. However it was not clear what peripheral or central mechanisms might explain these effects. The aim of this study was to test the effect of fatigue of each agonist/antagonist muscle group separately on position sense at the elbow and knee.

Four separate experiments of the same design were performed on Elbow Flexors, Elbow Extensors, Knee Flexors and Knee Extensors. In all experiments subjects performed a series of position matching trials pre and post-exercise. Maximum Voluntary Contraction force was also measured pre and post-exercise. Exercise of the target muscle involved repeated concentric contractions of one limb until a force deficit of 30% was achieved.

At the elbow, fatigue of either flexors or extensors led subjects to perceive the fatigued limb as more EXTENDED than it actually was. In contrast, at the knee fatigue of either flexors or extensors led subjects to perceive the fatigued limb as more FLEXED than it actually was.

While peripheral signals (motor or sensory) occurring during exercise may contribute to the observed position errors, the origin of these disturbances seem more likely to be explained by changes occurring within the brain.

MOVING A PHANTOM HAND

Lee Walsh, Simon Gandevia and Janet Taylor

Prince of Wales Medical Research Institute and the University of New South Wales.

The senses of limb movement and position are critical for accurate control of movement. Recent studies show that central signals of motor command contribute to the sense of limb position but it is not clear whether such signals influence the different sense of limb movement. Subjects participated in two experiments in which we inflated a cuff around their upper arm to produce an ischaemic block, paralysing and anaesthetising the forearm, wrist and hand. This produces an experimental phantom wrist and hand. With their arm hidden from view subjects made voluntary efforts with their blocked wrist. In the first experiment (n=8) efforts were 20% and 40% of maximum and were 2 s and 4 s in duration. The second experiment (n=6) used 1 s and 5 s efforts of 5% and 50% of maximum. Subjects signalled perceived movements of their phantom wrist using a pointer. All subjects reported clear perceptions of movement of their phantom hand for all levels and durations of effort. On average, subjects perceived their phantom wrist to move between 16.4 º ± 3.3 º (mean ± 95% CI) and 30.2 º ± 5.4 º in the first experiment and between 10.3 º ± 3.5 º and 38.6 º ± 6.7 º in the second. The velocity of the movements and total displacement of the phantom graded with the level of effort, and the total displacement also graded with duration. Hence, we have shown that motor command signals have a novel proprioceptive role in the perception of movement of human joints.

POSSIBLE TENDON ORGAN INHIBITION IN HUMAN GASTROCNEMIUS

Khan S.I. and Burne J.A.

University of Sydney and Prince of Wales Medical Research Institute, Sydney, Australia

Electrical stimulation of the Achilles tendon (TES) produced strong reflex depression of a small background contraction in both heads of gastrocnemius via large diameter electrodes localized to the tendon. In this study, the contribution of presynaptic and postsynaptic mechanisms to the depression was investigated by studying conditioning effects of tendon afferent stimulation on the mechanical tendon reflex (TR) and motor evoked potential (MEP). TES completely inhibited the TR over an interstimulus interval of 300 ms that commenced before and continued during and after the period of voluntary EMG depression. Tendon afferent conditioning stimuli also partially inhibited the MEP, but over a short time course confined to the period of voluntary EMG depression. The strength and extended time course (>250 ms) of tendon afferent conditioning of the TR and its failure to produce a similar depression of the MEP are consistent with a mechanism involving presynaptic inhibition of Ia terminals by fast conducting tendon afferents. In contrast, sural nerve conditioning partially inhibited the TR and MEP over a short time course (ISI <100 ms) resembling the inhibition seen in the voluntary EMG. This was consistent with the postsynaptic origin of cutaneous inhibition of the motoneurons.

PAIN ALONE DOES NOT INTERFERE WITH MOTOR CORTICAL PLASTICITY

Kylie Tucker, Damian Ingham, Henry Tsao, Paul Hodges

University of Queensland

Short-term training of a novel task can induce motor plasticity of the corticomotor pathway. Training induced motor plasticity has been shown to be compromised by pain, but, decreased ability to perform motor training during pain may be responsible for this reduced plasticity. . AIM: To investigate the effects of pain on training induced plasticity of the corticomotor pathway, with control of training performance and distraction from the training task by pain. METHODS: Transcranial magnetic stimulation (TMS) was delivered over the motor cortex of 9 volunteers to determine the optimal site to elicit index finger abduction movements. Subjects performed repeated index finger adduction movements (3x8 minute training sessions). TMS was applied to the same site before and immediately after each training sessions, and after 3x5 minute recovery periods. Acceleration of the index finger was recorded throughout the training and TMS periods. Training induced motor plasticity was measured by changes in TMS evoked finger acceleration after training in a control, local and remote pain condition. Pain (~6/10) was induced by repeated bolus injections of hypertonic saline. RESULTS: Subjects performed the training task equally between conditions. Peak acceleration of finger movement into abduction induced by TMS was reduced ($P<0.01$) following motor training into adduction during the control and local pain conditions. This change was not observed during the remote pain condition. CONCLUSIONS: When a training task is performed well during pain, pain alone does not interfere with motor plasticity. Distraction from the trained body part, by remote pain, can interfere with learning, despite equal performance of the training task.

INTRIGUING RELATIONSHIPS BETWEEN BODY IMAGE, MOTOR OUTPUT, PAIN AND AUTONOMIC CONTROL

Lorimer Moseley

Prince of Wales Medical Research Institute

The feeling that we have of our own body, its size and shape and that we own it, constitutes a fundamental aspect of self-awareness and is widely held to be important for motor control. This bodily awareness, labeled here as body image, is thought to be in part innate and in part constructed, and modified, by ongoing proprioceptive input from the body. Body image, and motor output, is disrupted in people with chronic pain. We have begun interrogating the relationship between body image, motor output, pain and autonomic control and have made some intriguing discoveries. First, we have established that when one disrupts the sense of ownership we have over an arm, that arm becomes cooler and processing of tactile input is modified. Second, when people with chronic arm pain and autonomic disturbance perform arm movements while they watch the painful arm, the effect of movement on pain and swelling is modulated by whether their view of the arm is magnified, minified or unchanged. Third, when amputees learn an entirely novel movement with their phantom arm, they report a simultaneous change in the felt anatomical structure of their phantom. This talk will briefly describe the studies behind these findings.

Session 6: Efferent Matters 11.15 am – 1.00 pm

TRAINING-RELATED CHANGES IN HUMAN MOTOR UNIT ACTIVITY

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Although recording single motor unit activity is a relatively simple procedure, assessing the effect of a training intervention is more challenging. The most common technique used to record motor unit potentials in humans is an intramuscular electrode, which can comprise either a set of fine wires or a needle. The technical limitation in this field is the ability to discriminate the potentials of single motor units in multi-unit recordings. Despite recent improvements in hardware and software to record motor unit activity, relatively few studies have directly compared motor unit behaviour before and after training. Examples from motor unit studies involving strength training and eccentric exercise will be discussed. After short-term (4-8 weeks) strength training, the most commonly observed change in motor unit activity is an increase in maximum motor unit discharge rate in young and old adults. However, increases in strength with training are not accompanied by changes in motor unit synchronization. In contrast to strength training, eccentric exercise results in muscle weakness and soreness, which is accompanied by short and long-term changes in motor unit activity. We have recently shown that eccentric exercise increases motor unit recruitment and minimum motor unit discharge rates for at least 24 hours, and new evidence shows that motor unit synchronization is increased for at least 7 days after eccentric exercise. Further studies are needed to elucidate the changes in motor unit activity with these forms of training, particularly during high force contractions.

RELATION BETWEEN LOW-FREQUENCY COMPONENTS IN MOTOR UNIT DISCHARGE RATES, FORCE AND THE EEG

Dario Farina & Francesco Negro

Center for Sensory-Motor Interaction (SMI), Department of Health Science and Technology, Aalborg University, Denmark

Oscillations at approximately 20 Hz in the EEG signal in humans are coherent with the surface EMG during sustained contractions (Conway et al. 1995). This association, which is called cortico-muscular coherence, is believed to arise from the effective transmission of cortical activity through the cortico-spinal tract and the monosynaptic connections to the motor neurons (Baker et al 2003). Descending and afferent inputs have several divergent projections on the motor neurons (Lawrence et al 1985; Ralston et al 1984), thus the motor neuron pool is mainly controlled by a largely spread synaptic input. The motor neurons integrate the inputs they receive to produce the neural drive to the muscle, thus transducing synaptic input into force. Only the low-frequency components of the neural drive are reflected into the motor output (Mannard & Stein 1973). Accordingly, in this presentation it will be shown that the effective drive to the muscle can be described by a low-dimensional signal, extracted by methods of dimensionality reduction from the correlated activity of a fraction of the population of active motor units. This low-dimensional signal explains the majority of the variability in the

generated force. Moreover, the detection of the activity of a relatively small fraction of motor units allows the direct identification of coherence between the pooled motor unit activity and the EEG signal.

Conway et al. (1995). J Physiol 489:917-924
Baker et al. (2003). J Neurophysiol 95:3904-3910
Lawrence et al. (1985). J Comp Neurol 232:499-510
Ralston et al. (1984). J Neurophysiol 51:777-792
Mannard & Stein (1973). J Physiol 229:275-96

CAN NEURAL SYNCHRONIZATION DIFFERENTIATE BETWEEN SOURCES OF DESCENDING INPUT TO A MOTONEURONE POOL?

Tjeerd Boonstra[a,b], Bernadette van Wijk[c] and Andreas Daffertshofer[c]

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[b] *Black Dog Institute, Sydney, Australia*
[c] *Research Institute MOVE, VU University Amsterdam, The Netherlands*

Using electroencephalography (EEG) and electromyography (EMG), corticomuscular and intermuscular synchronization have been found in different frequency bands and under different task conditions. These different synchronization characteristics may indicate that distinct neural mechanisms play a role in different types of long-range synchronization. Here we tested whether intermuscular synchronization between first dorsal interosseous (FDI) muscle and flexor pollicis brevis (FPB) muscle of both hands originates from the same underlying process as corticomuscular synchronization. To this end, we compared time-resolved EMG–EMG and EEG–EMG coherence in a bilateral precision-grip task. Whereas bilateral EMG activity was synchronized at 7-13Hz during the change from increasing to stable force production, EEG–EMG coherence was found at 15-30Hz during stable force production. The disparities in time–frequency profiles indicate different mechanisms contributing to corticomuscular and intermuscular synchronization. In addition, the absence of synchronization between cortical activity and common spinal input at 10 Hz renders a cortical source unlikely. Intermuscular coherence between homologous muscles therefore augments the more-established technique of corticomuscular coherence and may be used to investigate projections of different neural structures onto MU pools.

CORTICAL AND NON-CORTICAL MUSCLE ACTIVATION FOR BALANCE.

Richard Fitzpatrick
Prince of Wales Medical Research Institute

PROPERTIES OF RECTIFIED AVERAGES

Jim Colebatch

University of New South Wales Clinical School and Prince of Wales Medical Research Institute, Sydney NSW 2031 Australia

Averages of rectified EMG activity (“rectified averages”) have been traditionally used to detect excitation and inhibition. However, the sudden onset of inhibition of tonically-active EMG itself evokes an additional wave which adds to the ongoing activity. This is the basis of the VEMP (vestibular evoked myogenic potential: Colebatch et al. (1994)) but is also important because it can lead to paradoxical peaks in rectified averages of EMG (“early exteroceptive component” or EEC: Widmer and Lund, 1989) and thereby delay or obscure the detection of inhibition (Rothwell JC, 2007). The evoked waves (EEC or VEMP) can also be recorded using unrectified averages. For a constant added waveform, the corresponding rectified average can be predicted if the tonic level of activity is known. However, for the VEMP at least, this does not completely explain the properties of the rectified averages obtained in practice (Colebatch JG, 2009). Accurate modelling of rectified averages obtained in subjects requires consideration of the additional effect of temporal jitter of the underlying waveform.

Colebatch JG et al. (1994). *J Neurol Neurosurg Psychiatry* 57: 190-197.
Colebatch JG (2009). *Exp Brain Res* 199:167-176.
Rothwell JC (2007). *J Physiol* 584: 363.
Widmer CG, Lund JP (1989). *J Neurophysiol* 62: 212-219.

1. HOMONYMOUS AND HETERONYMOUS IA-EXCITATION OF VASTUS LATERALIS AND MEDIALIS MOTOR UNITS.

Benjamin K. Barry & Sean Kelly

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Afferent inputs to the quadriceps motoneurone pool were measured for 24 motor units (11 VL, 13 VM; 5 subjects) in response to stimulation of the femoral nerve (homonymous: 0.9x MT, lower of the quadriceps M-wave or H-reflex) and the posterior tibial nerve (heteronymous: 1.2x MT for soleus H-reflex). Stimuli were delivered randomly to each nerve (599 ± 132 stimuli, range: 450 – 950) while subjects maintained voluntary discharge of a quadriceps motor unit (8.6 ± 1.1 pps) for between 400 and 1250 s, with interspersed rest periods. Clear and significant peaks (12.5 ± 7.3 counts per 100 stimuli, $P < 0.005$) were observed in the post-stimulus time histograms (PSTH) for 63% of motor units in response to homonymous stimulation (latency: 22.0 ± 5.7 ms, width 2.3 ± 0.9 ms), but were not apparent for heteronymous stimulation. This excitation, presumably Ia in origin, was similar for the small samples of low-threshold VL and VM motor units. PSTH peaks were observed for 73% of VL motor units (10.5 ± 5.1 counts per 100 stimuli) and 54% of VM motor units (14.7 ± 9.0 counts per 100 stimuli). Stimuli were delivered randomly so that peri-stimulus frequencygrams (PSF) could be generated. The PSF data consistently supported the PSTH data and did not appear to add any additional information. This supports the use of spike-triggered stimulation, requiring fewer stimuli, to further investigate the strength and distribution of monosynaptic Ia-excitation of the quadriceps motoneurone pool.

2. THE SHORT AND LONG LATENCY STRETCH REFLEX COMPONENTS, M1 AND M2, CAN BE DIFFERENTIATED BY THE FREQUENCY CONTENT OF THE STRETCH

Serajul Khan and **John Burne**

Discipline of Biomedical Science, Sydney Medical School, University of Sydney, NSW, 2006.

The short latency (M1) stretch reflex is attributed to a spinal monosynaptic loop but the origin of the longer latency (M2) response is less clear. Possible pathways include a group 1 mediated transcortical loop and spinal group II or cutaneous afferent stimulation. The current study obtained M1 and M2 responses from flexor digitorum indicis by tapping the tendon with a probe attached to a linear motor during a small background contraction. By applying a digital low pass filter to the input waveform of the linear motor, the frequency content of the stretch was reduced in several incremental steps. The pooled results from six subjects showed the peak amplitude of the short latency M1 response to be progressively reduced to zero over the band 400 – 5 Hz pass. The M2 component in contrast was not significantly affected by the filter as the response amplitude remained flat over the same frequency band. The implication is that different afferents drive M1 and M2.

3. VENTILATION AND EFFORT IN ISOMETRIC CONTRACTIONS

Jane E. Butler, Janette L. Smith, Peter G. Martin, Rachel A. McBain, Janet L. Taylor

Prince of Wales Medical Research Institute, Randwick, NSW, 2031, Australia.

With exercise, ventilation increases both reflexly and through a central feedforward system related to motor commands. We studied whether increases in ventilation are directly related to voluntary drive. Subjects (n=8) made 10-s isometric elbow flexor contractions to 25%, 50% and 100% of maximal voluntary force (MVC) during normo- or hypercapnia with the left arm, right arm or both arms together. They also rated the effort to produce each contraction.

Ventilation was graded with contraction strength in normo- and hypercapnic conditions. Contraction-related increases in ventilation were unaffected by hypercapnia. Ventilation with 2-arm MVCs was not more than with 1-arm MVCs. Reported effort also graded with contraction strength. For 1-arm MVCs, effort was rated similarly in normo- and hypercapnia. Although perceived effort rose by 17% with 2-arm contractions, it did not double.

In a second study, subjects contracted the right elbow flexors, right knee extensors or both muscle groups. Here, ventilation increased similarly for arm or leg contractions, and for contractions of both limbs. Reported effort was the same for arm or leg contractions, and only slightly higher for the 2-limb contractions.

We conclude that the increase in ventilation during brief static efforts is not mediated by feedback from the periphery. Furthermore, ventilation is not directly related to the output from the motor cortex to the exercising muscles. These same conclusions are true for subjects' reported effort. In brief contractions, both the ventilatory response to exercise and perceived effort seem to derive from central signals which arise from motor areas other than the primary motor cortex.

4. SYNAPTIC PLASTICITY IN IPSILATERAL MOTOR CORTEX FOLLOWING UNILATERAL BALLISTIC PRACTICE

Alanna St.G. Cresp, Stephan Riek and Timothy J. Carroll

Perception and Motor Systems Laboratory, School of Human Movement Studies, The University of Queensland, St Lucia, QLD

It has long been observed that unilateral motor practice can improve performance of the opposite (untrained) limb. In this study, sixteen right-handed subjects practiced a ballistic finger movement task for four consecutive days with the right hand. The task has been shown to produce rapid, bilateral performance gains and increases in corticospinal excitability. We used paired associative stimulation (PAS) to investigate the capacity for synaptic plasticity in the ipsilateral (i.e. untrained) motor cortex, during early and late phases of motor learning. On day 0 (≥1 week before training), 1 (first day of training) and 4 (fourth day of training), PAS was delivered to the left ulnar nerve and right primary motor cortex (M1) with an interstimulus interval of 10ms (PAS_{10}, depresses cortical excitability at rest; n=8) or 25ms (PAS_{25}, enhances cortical excitability at rest; n=8). Motor evoked potentials (MEPs) were recorded from left first dorsal interosseus (FDI) before and after training and monitored for 30min post PAS. Left and right hand performance improved with training. On day 0, PAS_{10} reduced corticospinal excitability to 75% of baseline and PAS_{25} did not change corticospinal excitability from baseline. In contrast, MEP amplitude *increased* to 250% of baseline following PAS_{10} on day 1 but did not change from baseline on day 4. Corticospinal excitability did not change following PAS_{25} on day 1 or day 4. These preliminary results indicate changes in the capacity for synaptic plasticity (i.e. metaplasticity) in the ipsilateral M1 in early stages of skill acquisition.

5. MOTOR TRAINING IN A BALLISTIC TASK BUT NOT A VISUOMOTOR TASK INCREASES THE RESPONSE TO STIMULATION OF THE CORTICOSPINAL AXONS.

Sabine Giesebrecht *, Hiske van Duinen*, Gabrielle Todd†, Simon C. Gandevia *, and Janet L. Taylor*

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Short periods of training in motor tasks can increase motor cortical excitability (1, 2). This study investigated whether changes also occur at a subcortical level.
Subjects trained in ballistic finger abduction or visuomotor tracking. Subjects sat with the right index finger in a splint which rotated about the metacarpophalangeal (MCP) joint. Surface EMG was recorded over the first dorsal interosseus. Transcranial magnetic stimulation (TMS) over the back of the head (double-cone coil) elicited cervicomedullary motor evoked potentials (CMEPs) by stimulating corticospinal axons. TMS over the motor cortex (figure-8 coil) elicited motor evoked potentials (MEPs). Responses were recorded from relaxed muscle before and after training. In study 1 (n=15), training comprised of 2x150 maximal finger abductions. Feedback of acceleration was provided. Acceleration ($p<0.0001$) and EMG ($p<0.0001$) increased with training. CMEPs also increased to 248±152% of baseline immediately after training ($p=0.007$) but returned to control (155±141%) 10 min later. MEPs were unchanged. In study 2 (n=15), subjects used a potentiometer signal of MCP joint angle to follow a pathway on a computer screen. After ~ 30 min of training, tracking improved as shown by increased cross correlation between joint angle and the target pathway ($p<0.0001$), reduced time lag ($p<0.0001$) and reduced EMG ($p<0.0001$). However, neither CMEPs nor MEPs were changed.
Transmission through the corticospinal pathway at a spinal level increased after repeated ballistic movements but not after training in a visuomotor task. Thus, changes at a spinal level may contribute to improved performance in some motor tasks.

1. Pascual-Leone A, Nguyet D, Cohen LG, Brasil-Neto JP, Cammarota A, Hallet M (1995). J Neurophysiol 74, 1037-1045.
2. Latash ML, Yarrow K, Rothwell JC. Exp Brain Res, 151, 60-71, 2003

6. ENCODING MOTOR ACTION WITH WAVES

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5. Queensland Institute of Medical Research, Brisbane, QLD. 6. Royal Brisbane and Women's Hospital, QLD.

Synchronous spiking and spatiotemporal waves of spiking activity have recently emerged as ubiquitous phenomena in the cortex, however the functional role of these spatiotemporal spiking patterns is not understood. Previous studies have proposed that transitions from waves to synchrony in sensory cortex correspond with stimulus recognition. Here, we demonstrate that similar transitions in motor cortex may also play a role in motor behaviour, though in this case the transitions are reversed. We numerically simulated a small region of motor

cortex as a two-dimensional array of phase-coupled neural oscillators that could be switched between waves and synchrony by manipulating the relative contributions of inhibitory and excitatory connections in the synaptic kernel. We also modelled spinal motor units that received converging corticospinal projections from the cortex and acted as spatial filters capable of discriminating specific patterns of wave activity in the cortical array. By prescribing a fixed set of muscle activations to these motor units and manipulating the synaptic kernel to toggle the cortical activity between waves and synchrony, we were able to move a simulated biomechanical limb between its rest position (cortical synchrony) and a predetermined limb posture (cortical waves). Moreover, the net oscillatory activity in the cortical array attenuated dramatically during wave activity, consistent with the observed attenuation of local field potentials in monkey motor cortex during voluntary movements.

7. AN INVESTIGATION OF LONG-INTERVAL 'INTRACORTICAL' INHIBITION IN A HAND MUSCLE

CJ McNeil, PG Martin, S Giesebrecht, JL Taylor and SC Gandevia

Prince of Wales Medical Research Institute and UNSW, Randwick, Australia

When two cortical stimuli are delivered at an interstimulus interval (ISI) of 50-200ms, the response (motor evoked potential; MEP) to the second stimulus is typically suppressed. This phenomenon is termed long-interval intracortical inhibition (LICI). However, recent data demonstrate that the inhibition can be spinal rather than cortical (McNeil et al., J Physiol, 2009) and that facilitation rather than inhibition is possible (unpublished observations). **Purpose:** To explore the influences of contraction strength and test stimulus intensity on LICI. **Methods:** MEPs were evoked in first dorsal interosseous by transcranial magnetic stimulation over the motor cortex (n=9). Single test and paired conditioning-test stimuli (100ms ISI) were delivered at rest or during brief contractions of 10, 25 or 100% maximal voluntary contraction (MVC) force. To quantify inhibition or facilitation, the conditioned MEP was expressed as a percentage of the unconditioned. **Results:** Unconditioned MEP size increased markedly from rest to 10% MVC but decreased between 25 and 100% MVC. It increased with stimulus intensity at all but 100% MVC. Conditioned MEPs increased progressively with contraction strength and stimulus intensity. At all stimulus intensities, inhibition increased from rest to 10% MVC and decreased between 25 and 100% MVC. At all contraction levels, increasing stimulus intensity decreased inhibition of the conditioned MEP. At rest and 100% MVC, the conditioned MEP was facilitated rather than inhibited with strong stimulus intensities. **Conclusion:** The effects of conditioning stimulation on an MEP vary greatly with contraction strength and test stimulus intensity. The term LICI may apply to only a small part of this relationship.

8. CHANGES IN MUSCLE DRIVE AS A FUNCTION OF AGE.

Danielle McMullen, Jocelyn Bowden, **Penelope McNulty**

Prince of Wales Medical Research Institute, Sydney

The properties of muscles and nerves change with age. Although a muscles maximum force decreases with age, the neural drive or voluntary activation, does not. Subtle changes in motor axon excitability have been reported as a function of age, although not a change in the amplitude of the maximum muscle response. We studied voluntary activation of adductor pollicis muscle and axonal excitability of this muscles nerve supply in the same subjects to examine these apparent conflicts. Forty healthy subjects were studied aged 20-79 years, 10 per decade, 5 male, 5 female. Surface EMG was recorded from adductor pollicis with isometric force acting on the first metacarpophalangeal joint. The ulnar nerve was stimulated immediately proximal to the wrist. Median activation score did not change with age groups but there was a significant difference in the amplitude of the maximum voluntary contraction ($p<0.001$), peaking at 95.53 Nm in the 60s. Median activation scores were highest in the 60s (93.3) and lowest in the 20s (90.5). Changes with age in ulnar nerve axonal excitability measures differed from those reported for the median nerve, most noticeably the amplitude of the maximum muscle response ($p=0.001$) and the slope of the stimulus response curve ($p=0.01$). There was no change in rheobase or response latency with age. These results suggest there are subtle changes with age in the physiological elements underpinning motor control and the interactions of these mechanisms. Some of these changes may be specific to the muscle and nerve being studied.

9. CENTRAL FATIGUE OF THE PELVIC FLOOR MUSCLES

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Background: Animal and human studies indicate that pelvic floor muscles fatigue more rapidly than striated skeletal limb muscles. This is counterintuitive considering the high proportion of slow twitch muscle fibres. Instead the greater fatigue could be due to central mechanisms. Here we aim to compare the degree of central fatigue in pelvic floor muscles with that of limb muscles. *Methods:* In six healthy subjects force and surface EMG

responses to transcranial magnetic stimulation (TMS) and brachial plexus stimulation were measured in the right biceps brachii. Pressure and surface EMG (measured with an anal probe) were measured for the pelvic floor muscles during TMS and sacral stimulation. Session order was randomised across subjects. Central fatigue was produced in both muscle groups using ten sustained (20 s) maximal voluntary contractions (MVCs) with a brief 2 s rest between each contraction. During each sustained MVC, three TMS stimuli were delivered at 5 s intervals. Voluntary activation was assessed during each MVC using the superimposed twitch force elicited by TMS. *Results:* In biceps brachii voluntary activation declined on average by 9 % ($p = 0.033$). In contrast, voluntary activation in the pelvic floor muscles declined by 46 % ($p = 0.002$). *Conclusion:* These findings suggest that pelvic floor muscles are more susceptible to central fatigue than limb muscles. The mechanism underlying greater central fatigue is unclear but is important for the design of rehabilitation programs in those with pelvic floor dysfunction where improved central drive may be of greater benefit than increased strength.

10. DIFFERENTIAL EFFECT OF LEVODOPA ON SPEECH AND LIMB FUNCTION IN PARKINSON'S DISEASE

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Discipline of Biomedical Science, Sydney Medical School, University of Sydney

Rigidity and bradykinesia of the limbs in Parkinson's disease (PD) are responsive to levodopa, based on clinical ratings. However, the dysarthria, dysphonia and dysphagia in PD appear less responsive clinically but quantitative data is lacking. We compared the effect of levodopa on parallel measures of ballistic adduction/abduction movements of the index finger and a range of speech parameters.
Finger data included surface EMG from the first dorsal interosseous muscle and joint angle of the first metacarpophalangeal joint. Finger data was collected once in a 'self timed condition' and once again repeating the same task with external timing cues. Speech data included acoustic records and EMG from the submental complex during extended vowel phonation and syllable repetition. Measures of acoustic perturbation, voice onset time and EMG bursts were extracted. Measurements were taken once in the control group (n=11) and before and after levodopa in the experimental group (n=13). The motor section of the UPDRS rating scale was used to assess ambulatory function in the experimental group.
Burst duration, burst area, amplitude and rise time as a percentage of duration were significantly different ($p<0.05$, unpaired t-test) between the control and experimental groups during finger abduction/adduction. These measures improved in the medicated state in congruence with a significant improvement in UPDRS scores ($p<0.05$, paired t-tests).

11. DELAYED ONSET MUSCLE SORENESS DOES NOT ALTER EXCITABILITY OF THE MOTOR CORTEX OR MOTONEURONES

Janet L Taylor, Nivan Weerakkody, Peter G Martin and Simon C Gandevia

Prince of Wales Medical Research Institute and the University of New South Wales

Unaccustomed eccentric exercise is often followed 1-2 days later by delayed onset muscle soreness (DOMS). Muscle pain induced by intramuscular hypertonic saline alters the excitability of motoneurones and motor cortical neurones (1) , but little is known about the effects of DOMS. We investigated the effect of muscle pain associated with DOMS on motor evoked potentials (MEPs) and cervicomedullary motor evoked potentials (CMEPs). Initially, subjects (n=7) performed eccentric elbow flexor contractions with the non-dominant arm until maximal voluntary force fell by 40%. One day later, EMG was recorded with surface electrodes over biceps brachii bilaterally. A tender site was located in exercised biceps and graded pressure applied. Two painful pressure levels were chosen. Transcranial magnetic stimulation evoked MEPs and electrical transmastoid stimulation evoked CMEPs in the biceps of one arm. With the arm at rest, responses were collected with no pressure and then during intermittent applications of pressure. Subjects reported the level of muscle pain after each application. The protocol was repeated on the other arm. Pain levels during pressure were higher in the exercised (2±0.4 and 3.4±1) than the control arm (0.4±0.5 and 0.9±0.8; $p=0.002$). With no pressure, MEP and CMEP areas were similar in the exercised (9.4±2.9 and 8.5±4.3% of maximal Mwave, respectively) and unexercised arm (9.2±4.6 and 9.5±3.7%). With pressure, MEPs increased in size ($p=0.003$) and CMEPs did not. However, there was no difference between arms ($p=0.153$). Thus, muscle pain elicited by pressure during DOMS did not alter excitability of the motoneurones or the motor cortex.

1. Martin et al. (2008) J Physiol 586 1277-1289.